

# HYDROBIOLOGIA

## ACTA HYDROBIOLOGICA HYDROGRAPHYCA ET PROTISTOLOGICA

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# Quelques organismes sporadiques du plancton de la région d'Amsterdam

par

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Au cours d'un examen hydrobiologique des eaux de surface de la commune d'Amsterdam, qui s'étendit sur un laps de temps d'environ 10 années (1946—1956), on réussit à rassembler environ 3000 échantillons de provenances diverses.

Le matériel obtenu fut immédiatement fixé au formol. Les éléments, qui se trouvaient suspendus dans 1 litre d'eau ou dans une quantité de 10 litres filtrée par de la gaze de soie au cours du prélèvement de l'échantillon, subirent une concentration jusqu'à 2 cm<sup>3</sup>, qui fut suivie d'un examen au microscope.

Au cours de la période nommée de l'expérience, on ne rencontra qu'à 8 reprises et encore par exemplaires rares ou uniques, des formes qui s'avérèrent appartenir à l'ordre des Actinomyxidies.

Les Actinomyxidies constituent un petit groupe d'organismes dans la sous-classe des Cnidosporidies (classe des Sporozoaires), qui parasitent soit dans la cavité générale soit sur l'épithélium intestinal des Oligochètes et des Sipunculoides. STOLC a été le premier à découvrir ces parasites en 1889; il établit l'ordre des Actinomyxidies. Au cours de son cycle évolutif le parasite forme une spore triradiaire qui comprend 3 capsules polaires (fig. I, 1). Chaque capsule polaire contient un filament qui possède la faculté d'expulsion.

Les filaments polaires servent à l'ancrage de la spore dans le corps de l'hôte. Les exemplaires examinés par nous ne présentaient en général qu'un seul filament expulsé; les 3 filaments n'étaient que fort rarement tous visibles simultanément.

La forme, que nous avons rencontrée le plus souvent, était pourvue de trois prolongements épineux, dont les extrémités étaient fermées.

Ceux-ci ont apparemment la fonction de maintenir l'organisme en flottaison dans l'eau, en vue d'en favoriser la dispersion (fig. II, 1).

La soi-disant masse germinale (fig. II, 2), qui contient les 3 capsules polaires, se trouve au sein d'un quatrième processus. L'enveloppe sporale toute entière est hyaline et adhère légèrement à la lame

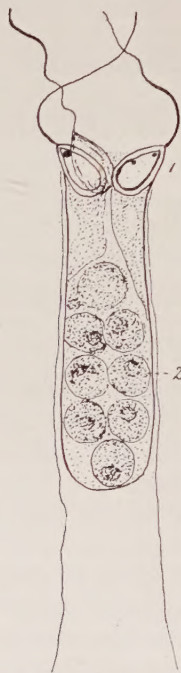


Fig. I *Triactionmyxon ignotum* masse germinale de la spore

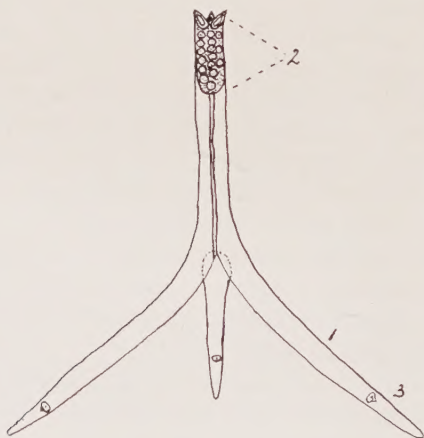


Fig. II *Triactinomyxon magnum* spore

porte-objet ou à la lamelle couvre-objet pendant la réalisation d'une préparation pour le microscope.

La viscosité de l'enveloppe sporale n'est toutefois pas tellement grande, que des particules étrangères qui se trouvent dans l'eau puissent se fixer sur la surface de la spore.

Dans le lumen de chacun des processus se terminant en entonnoir fermé. Se trouve un noyau résiduel (fig. II, 3), provenant de la cellule qui donna naissance à cette partie de la spore (cellule valvaire).

La spore entière, sans filament polaire, mesure environ 200  $\mu$ . Les dimensions de la masse germinale, dont la couleur est protoplasmique, sont de 35  $\mu$   $\times$  10  $\mu$ ; tandis que le filament polaire expulsé mesure environ 24  $\mu$ .

Une détermination plus poussée nous amena à la famille des Euactinomyxidies GRANATA 1925. POISSONS (1953) dénomme cette famille Synactinomyxidies. Les genres de cette famille parasitent exclusivement dans les Tubificidies.



Fig. III *Triactinomyxon ignotum*

Le corps germinal des spores représentées aux figures I et III contient 8 corpuscules uninucléés (germes amoeboïdes) (fig. I, 2) ce qui correspond au genre *Triactinomyxon ignotum* STOLC. Ce parasite vit dans le *Tubifex tubifex*.

Appartenant au genre *Triactinomyxon* les espèces suivantes sont en outre connues:

Contenant 16 germes amoeboïdes, *T. magnum* GRANATA

Contenant 24 germes amoeboïdes, *T. legeri* MACKINNON et ADAM

Contenant 32 germes amoeboïdes, *T. dubium* GRANATA

Contenant 50—100 germes amoeboïdes, *T. mrazeki* MACKINNON et ADAM.

Au sujet de la forme *T. magnum* (fig. II), également signalée par nous, on mentionne que celle-ci vit dans le *Limnodrilus udekemianus* tandis que les autres espèces sont toutes des parasites du *Tubifex tubifex*. Une seule fois nous avons trouvé une agglomération de masses germinales formant colonie (fig. IV). Les processus hyalins des spores avaient une plus grande coupe que chez les deux espèces déjà nommées, notamment 17  $\mu$ . Les parois présentaient à certaines distances de légers étranglements et des renflements circulaires (fig. V, 4), tandis que les extrémités étaient moins effilées (fig. V, 6) que celles des spores de *T. ignotum* et de *T. magnum*. Les masses germinales situées à l'orifice de l'autre extrémité des tubes, contenaient chacune 32 germes amoeboïdes (fig. V, 3); les dimensions en étaient de 32  $\mu$   $\times$  17  $\mu$ . Comme le montre le schéma (fig. V, 8), il existe un rattachement entre un des processus fermés de la spore et celui d'une autre spore, ce qui permet la formation de colonies, dont nous avons parlé plus haut.

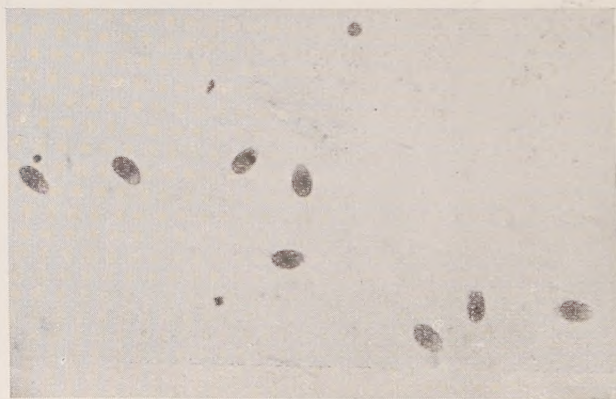


Fig. IV *Triactinomyxon dubium*

Cette forme doit être dénommée *T. dubium* en raison de la présence de 32 germes amoeboïdes. Nous faisons ici toutefois la remarque que la structure des enveloppes sporales n'a pas été décrite.

La libération des spores du corps des Oligochètes ne semble pas dans nos eaux dépendre d'une période déterminée de l'année. Nous les avons rencontrées en mars, avril, juin, juillet, octobre et novembre.

Dans la région d'Amsterdam, les habitats étaient l'Amstel, l'étang de la machine d'épuisement de Parc Zuiderzee (Zuiderzeepark), le fossé de drainage le long du square Archimède (Archimedesplant-

soen) dans le Watergraafsmeer et le canal Erasmus (Erasmusgracht) auprès du Hoofdweg.

La présence dans le plancton des spores des Actinomyxidies fut déjà mentionné par KOFOID au sujet de la rivière Illinois. Il s'exprime en ces termes:

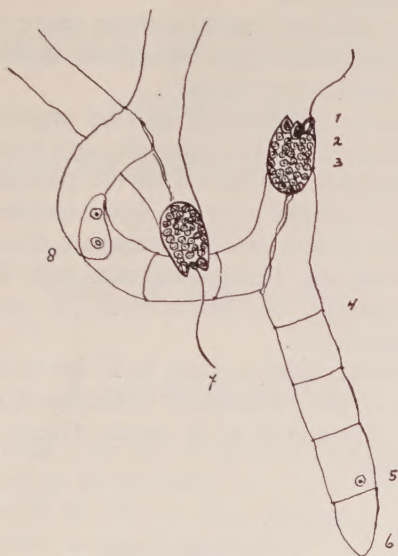


Fig. V *Triactinomyxon dubium*

1 et 7 filament expulsé, 2 capsule polaire, 3 germe amoéboïde, 5 noyau d'une cellule valvaire

„In the plankton collections of each year there have been found free limnetec spores which unquestionably belong to that highly aberrant and peculiar group of organisms described by STOLC ('99) as Actinomyxidias and regarded by him as Mesozoa, but later referred by MRAZEK ('00) CAULLERY and MESNIL ('04) and LEGER ('04) to the Myxosporidia. The organisms described by STOLC were parasitic in fresh-water oligochaetes, and it is not improbable that the limnetic spores taken in our plankton collections are derived from parasites in some of the numerous aquatic oligochaetes, or other invertebrates, found along the bottom and shores of the stream.

The species here referred to *Triactinomyxon* differs in some details from *T. ignotum* STOLC. It was found in the course of the six years at least once in every month of the year, but most regularly in May-September, and rarely and in small numbers in the colder months. Its transparency and long, slender, radiating, tripod-like arms give it a typically limnetic habit.

Actinomyxidias, gen. et sp. indet. - Clusters of eight, or less, cy-

lindrical spores radiating from a common center and bearing a marked resemblance in structural features to those of *Triactinomyxon*, but lacking any anchor-like projections, were found sparingly in the plankton in June-September.

The distinctively limnetic habit of these spore stages in the life-history of these parasites is unique among the Sporozoa, and has not, to my knowledge, been before noted".

(KOFOID dit dans ce qui précède que les organismes trouvés par lui dans la plancton, sont issus de parasites, qui vivent dans quelques Oligochètes. La présence des spores de ces parasites en eau limnétique est d'après lui unique pour les Sporozoaires).

Nous n'avons pas trouvé dans la littérature d'autres mentions de la présence de spores du *Triactinomyxon* dans le plancton. Pour autant que nous sachions, ces spores n'ont pas encore été signalées dans les eaux néerlandaises.

GRANATA cite comme habitats pour le *T. ignotum* l'île Stvanice en Bohème; la rivière Grève à Florence; Grenoble et Londres.

*T. magnum* est déjà connu de la rivière Grève à Florence et *T. dubium* de Grenoble.

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# Recherches sur les Rotifères des eaux saumâtres

## III. Quelques Rotifères de la Camargue

par

MARG. DE RIDDER (Gand).

### I. INTRODUCTION

Nous avons profité d'un court séjour en Camargue en avril 1957, pour récolter quelques échantillons des eaux saumâtres de la région. Tous proviennent de la réserve ornithologique locale, et pour pouvoir les récolter, nous avons dû solliciter l'autorisation de Monsieur G. TALLON, Directeur de la dite Réserve. Cette autorisation nous fut promptement et aimablement accordée, et nous remercions ici Monsieur TALLON de son obligeance.

Il est utile de signaler dès à présent, que nous comptons faire paraître une étude plus complète, comprenant un cycle annuel, sur les Rotifères de la même région. La présente contribution porte donc en quelque sorte un caractère préliminaire.

Les récoltes ont été effectuées, comme d'habitude, à l'aide d'un filet à plancton, comptant 77 mailles par cm. Le matériel a été fixé au formol 3%.

Pour autant que nous sachions, cette étude est la première à paraître sur les Rotifères de la Camargue. De ce fait, toutes les espèces trouvées sont nouvelles pour la région.

### II. MILIEU

Les stations des récoltes se situent comme suit: la moitié des échantillons a été prise aux environs de Salin de Badon, rive est de l'étang du Fournelet. D'autres échantillons ont été récoltés le long de la digue de mer, séparant le golfe de Beauduc des étangs. Enfin un dernier échantillon a été récolté aux étangs de Beauduc par Mr P. AGUESSE en octobre 1956 et mis à notre disposition, ce dont nous le remercions ici cordialement.

Quant aux principales caractéristiques des eaux, où ont été faites les récoltes, elles sont mentionnées dans le relevé des échantillons. Nous nous bornerons ici à ces quelques indications, et nous nous réservons de revenir à la question en détail dans l'ouvrage plus étendu que nous préparons actuellement sur les Rotifères de la Camargue.

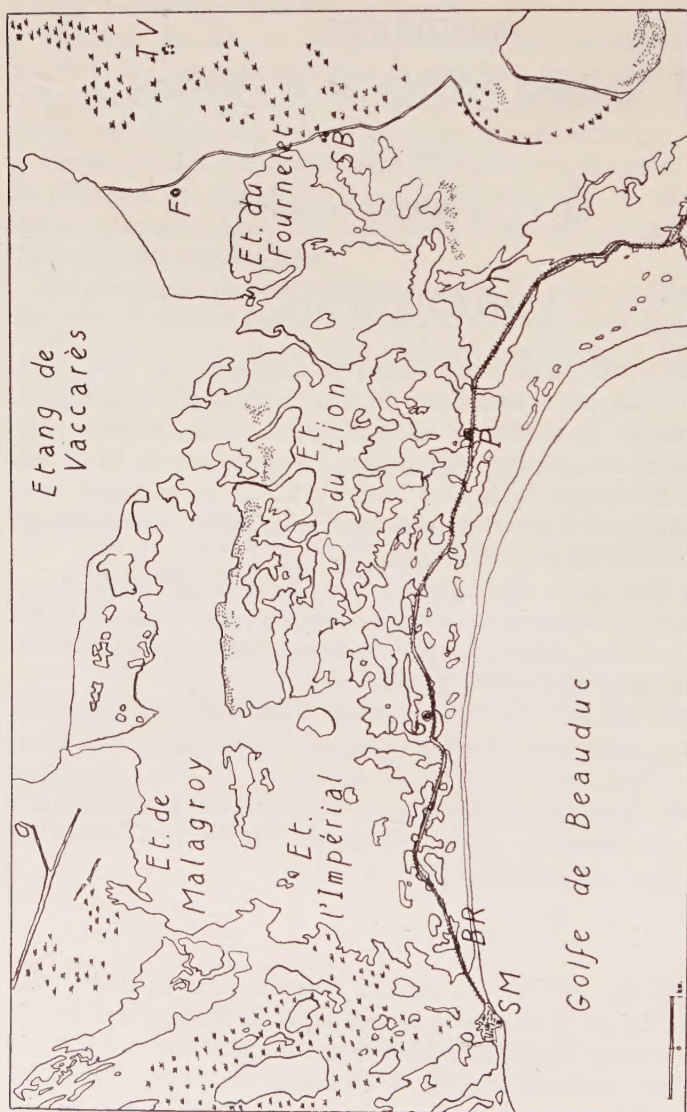


Fig. 1. La réserve ornithologique de la Camargue. Echelle 1/125.000.

SB = Salin de Badon; TV = la Tour de Valat; F = la Fielouse;

DM = Digue de mer; P = Phare de la Gacholle; G = Maison de Garde-digue;

BR = Baisse du Radeau; SM = Les Saintes Maries de la Mer.

### III. LISTE DES ÉCHANTILLONS

**1. Fossé avec végétation de *Lemna*, à l'entrée de la réserve à Salin de Badon.**

22 avril 1957, 12 h 30'.

temp. air =  $27,0^{\circ}$ , temp. eau =  $20,0^{\circ}$ , pH = 7,6.

teneur en chlorures = 2,130 g/l.

**2. Fossé longeant la route de Fiélouse à Salin de Giraud, à Salin de Badon.**

22 avril 1957, 12 h 40'.

temp. air =  $25,4^{\circ}$ , temp. eau =  $21,0^{\circ}$ .

pH = 8,6.

teneur en chlorures = 3,730 g/l.

**3. Fossé parallèle à celui de l'échantillon 1, à 100 m.**

22 avril 1957, 12 h 50'.

temp. air =  $28,0^{\circ}$ , temp. eau =  $19,2^{\circ}$ .

pH = 8,4.

teneur en chlorures = 8,520 g/l.

**4. — 5. Etang du Fournelet, rive sud-est.**

22 avril 1957, 13 h 50'.

temp. air =  $28,4^{\circ}$ , temp. eau =  $25,3^{\circ}$ .

pH = 8,8.

teneur en chlorures = 5,150 g/l.

**6. Flaque d'eau sur la rive sud-est du Fournelet.**

22 avril 1957, 13 h 40'.

temp. air =  $28,4^{\circ}$ , temp. eau =  $27,2^{\circ}$ .

pH = 8,6.

teneur en chlorures = 9,295 g/l.

**7. Fossé de l'échantillon 3, 1 Km plus au sud.**

22 avril 1957, 14 h 30'.

temp. air =  $24,0^{\circ}$ , temp. eau =  $27,1^{\circ}$ .

pH = 8,2.

teneur en chlorures = 17,395 g/l.

**8. Etang peu profond avec végétation dense de *Juncus*, 2 Km environ sud-ouest de Salin de Badon.**

22 avril 1957, 15 h.

temp. air =  $24,0^{\circ}$ , temp. eau =  $27,1^{\circ}$ .

pH = 8,5.

teneur en chlorures = 7,810 g/l.

**9. Fossé à joncs, près de Salin de Badon, entre les fossés des échantillons 1 et 3.**

22 avril 1957, 16 h.

temp. air = 26,3°, temp. eau = 24,0°.

pH = 8,6.

teneur en chlorures = 11,360 g/l.

**10. Digue de mer, au Phare de la Gacholle.**

26 avril 1957, 9h 30'.

temp. air = 15,5°, temp. eau = 16,1°.

pH = 8,5.

teneur en chlorures = 15,265 g/l.

**11. Digue de mer, à la maison de garde-digue (à l'ouest de l'étang des Batagnolles).**

26 avril 1957, 9 h. 45'.

temp. air = 15,7°, temp. eau = 17,1°.

pH = 8,1.

teneur en chlorures = 15,975 g/l.

**12. Digue de mer, 200 m. plus à l'ouest de 11.**

26 avril 1957, 10 h.

temp. air = 16,0°, temp. eau = 16,1°.

pH = 8,4.

teneur en chlorures = 18,105 g/l.

**13. Digue de mer, mare faisant partie de la baisse du Radeau, devant les Saintes Maries de la Mer.**

26 avril 1957, 11 h 30'.

temp. air = 16,0°, temp. eau = 16,0°.

pH = 8,4.

teneur en chlorures = 17,750 g/l.

**14. Echantillon pris par Mr. P. AGUESSE, au Beauduc.**

15 octobre 1956.

teneur en chlorures = 12,200 g/l.

#### IV. LISTE DES ESPÈCES TROUVÉES

Les espèces trouvées appartiennent toutes à la sous-classe *Monogononta*.

**Ordre Ploima.**

*Polyarthra remata* SKORIKOV, 1896

*Polyarthra dolichoptera* IDELSON, 1925.

*Epiphanes mollis* (HEMPEL, 1886).  
*Keratella quadrata* (MÜLLER, 1786).  
*Brachionus quadridentatus* HERMANN, 1783.  
*Brachionus plicatilis* MÜLLER 1786.  
*Notholca striata* (MÜLLER, 1786).  
*Notholca acuminata* HUDSON & GOSSE, 1886.  
*Euchlanis dilatata* EHRENBERG, 1832.  
*Lepadella patella* (MÜLLER, 1786)  
*Colurella adriatica* (EHRENBERG, 1831).  
*Colurella bicuspidata* (EHRENBERG, 1832).  
*Colurella colurus* (EHRENBERG, 1830)  
*Lecane nana* (MURRAY, 1913).

## Ordre Flosculariacea.

*Testudinella clypeata* (MÜLLER, 1786).

## V. REMARQUES CONCERNANT LES ESPÈCES TROUVÉES

### 1. *Polyarthra remata* et *Polyarthra dolichoptera*.

Ces deux espèces n'ont été trouvées que dans l'échantillon 1. Elles s'y trouvaient en quantités assez nombreuses.

Données écologiques:

température de l'eau = 20,0°.

pH = 7,6.

teneur en chlorures = 2,130 g/l.

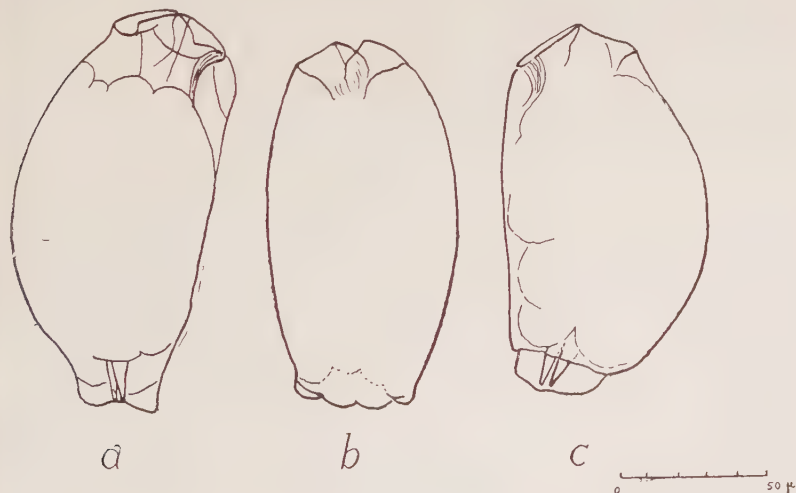


Fig. 2. *Epiphanes mollis* (HEMPEL).  
A et C: vue latérale; B = vue ventrale.

Distribution dans l'eau saumâtre:

Le distribution de ces deux espèces n'est pas très bien connue, vu que la plupart des auteurs les groupent comme *Polyarthra trigla* EHRBG.

Les seules données que nous ayons pu trouver sont les suivantes:  
Belgique:

*Polyarthra remata*: EVENS, 1954 (Hamme); DE RIDDER, 1957 b (Assenede).

*Polyarthra dolichoptera*: DE RIDDER, 1957 (Assenede).

## 2. *Epiphanes mollis*.

Cette espèce est trouvée être assez commune dans les échantillons 4 et 5.

Données écologiques:

température de l'eau = 25,3°.

pH = 8,8.

teneur en chlorures = 5,150 g/l.

HARRING (1913, pg. 22) range cette espèce dans le genre *Brachionus* sous le nom de *Brachionus mollis* HEMPEL (1896). Il ne connaissait apparemment aucune autre mention dans la littérature.

Suivant DE BEAUCHAMP (1932), *Notops macrourus* BARROIS ET DADAY (1894, Syrie) serait un synonyme de notre espèce, qu'il appelle *Notops mollis*. Les exemplaires de HEMPEL provenaient du fleuve Illinois (U.S.A.). Les autres récoltes connues ont été également faites hors de l'Europe, notamment:

BARROIS ET DADAY, 1903: Asie mineure.

—, 1907: Afrique.

APSTEIN, C., 1907 et 1910: Ceylan.

MURRAY, J., 1913: Amérique du Sud.

DE BEAUCHAMP, P., 1932: Afrique orientale.

Pour l'Europe, nous avons les indications suivantes:

NEIZVESTNOVA-JADINA, 1914 }  
FADÉEV, 1925 } U.R.S.S.

Enfin, pour la France, DE BEAUCHAMP (1907) a trouvé *Epiphanes mollis*, qu'il appelle *Brachionus mollis* HEMPEL aux environs de Bourg (Ain). A cette occasion, il écrit en 1932: „seule localité de France où je connaisse cette rare espèce, qui n'a guère été étudiée à l'état vivant”

Notre capture est donc la deuxième pour l'Europe occidentale et la première de l'eau saumâtre se trouvant en relation avec la mer.

Nous sommes heureuse de pouvoir y ajouter une troisième localité ouest-européenne; en effet nous avons trouvé cette espèce dans un échantillon récolté le 25 mai 1955 à Marchwood (Southampton water), côte du Hampshire, Angleterre, à une profondeur de 1 à 7 m,

à 14h 20' (marée haute), à une température d'eau de 13°,3 C et une salinité de 15 à 17,5‰. Cet échantillon avait été aimablement mis à notre disposition par Mr. le Professeur J. E. G. RAYMONT, de l'Université de Southampton. Nous le remercions ici bien sincèrement. C'est la première mention de *Epiphanes mollis* pour les Iles Britanniques.

### 3. *Keratella quadrata*.

Nous n'avons trouvé qu'un seul exemplaire de cette espèce, notamment dans l'échantillon 1.

Données écologiques:

température de l'eau = 20,0°.

pH = 7,6.

teneur en chlorures = 2,130 g/l.

C'est une des espèces les plus communes des eaux douces, que l'on ne rencontre que sporadiquement dans l'eau saumâtre. REMANE (1929) et RENTZ (1940) signalent toutefois que *Keratella quadrata* est commune dans le Mer du Nord. Les données disponibles sur la salinité des eaux, dans lesquelles l'espèce a été trouvée, vont jusqu'à 15,965 g/l. C'était notamment la teneur en chlorures pour le Zwin (Knokke, Belgique), où nous l'avons trouvée en très petite quantité (DE RIDDER, sous presse), donc notablement au-dessus de la teneur de l'échantillon 1 (2,130 g/l).

La „variété” *platei* JÄGERSKIÖLD qui est indiquée comme caractéristique pour l'eau saumâtre, est peut-être une bonne espèce, vu que la tolérance de *Keratella quadrata* nous paraît assez grande.

Distribution dans l'eau saumâtre:

a) en Europe:

Belgique: LOPPENS, 1908; GILLARD, 1948 (Nieuport)

VAN OYE, 1947; DE RIDDER 1957 (Assenede).

CRÉ, 1949 (polders de l'Escaut).

EVENS, 1954 (Hamme)

Pays-Bas: WIBAUT, 1922 (Zuiderzee).

OTTO, 1927 (environs de Leyde).

Allemagne: HAUER, 1925 (Oldesloe); RENTZ, 1940 (Rügen); WULFERT

1939 (Saale-Elster-Niederung) ALTHAUS 1957 (Environs de Halle-Saale).

Mer du Nord: REMANE, 1929.

Mer Baltique: IMHOF, 1886; LAUTERBORN 1905.

Espagne: WISZNIEWSKI, 1931 (environs de Valence).

Côte norvégienne: LIE-PETTERSON 1905.

Finlande: VÄLIKANGAS 1926 (port de Helsink).

Hongrie: NOGRADI, 1957 (environs de Fülöpzállás).

b) hors de l'Europe:

Asie: HADA, 1939 (Japon).

HAUER, 1957 (Lac de Van, Turquie).

Amérique du Nord: HARRING, 1921 (Alaska).

BRYCE, 1924 (N. Dakota, U.S.A.).

RAWSON, 1944 (Saskatchewan, Canada).

Amérique du Sud: MURRAY, 1913 (Brésil).

#### 4. *Brachionus quadridentatus*.

Cette espèce ne fut trouvée qu'en quelques exemplaires dans l'échantillon 2.

Données écologiques:

température de l'eau = 21,0°.

pH = 8,6.

teneur en chlorures = 3,730 g/l.

*Brachionus quadridentatus* est trouvé dans l'eau douce et saumâtre. Suivant REDEKE (1935) il est plus rare que *Brachionus angularis* GOSSE et se rencontre plus souvent dans l'eau saumâtre.

REMANE (1929) de même que RENTZ (1940) disent que cette espèce n'a jamais été trouvée dans la mer. D'après nos données, il est difficile de juger si nos exemplaires provenaient de la Méditerranée ou bien du Rhône. Nous devons donc laisser la question provisoirement ouverte. Quant à la salinité de l'eau, la seule donnée dont nous disposions jusqu'ici est celle de DE RIDDER (1957 b), notamment pour Assenede (Belgique): 260 à 300 mg/l.

Distribution dans l'eau saumâtre:

a) en Europe:

Belgique: LOPPENS, 1908 (Nieuport); GILLARD, 1948 (polders de la Flandre orientale); CRÉ 1949 (polders de l'Escaut); EVENS, 1954 (Hamme); DE RIDDER, 1957 (Assenede).

Pays-Bas: WIBAUT, 1922 (Zuiderzee).

Allemagne: DAHL, 1893 (embouchure de l'Elbe); WULFERT, 1939 (Saale-Elster-Niederung); RENTZ, 1940 (Rügen); ALTHAUS, 1957 (environs de Halle-Saale).

Iles Britanniques: HUDSON ET GOSSE, 1889 (côtes de l'Angleterre), GALLIFORD, 1945 (environs de Liverpool), GALLIFORD, 1948 (presqu'île de Wirral, Cheshire).

Mer Baltique: LAUTERBORN, 1905.

LEVANDER, 1901.

Finlande: VÄLIKANGAS, 1926 (environs de Helsinki).

Espagne: WISZNIEWSKI, 1931 (environs de Valence).

Hongrie: NOGRADI, 1957 (environs de Fülopszállás).

U.R.S.S.: RYLOW, 1933 (Mer Caspienne, mer d'Azow, Russie sud-orientale).

b) hors de l'Europe:

Asie: VAVILOV, 1928 (Kamysch-Samara, Sibérie).

HADA, 1939 (Japon).

Afrique: BRYCE, 1931 (Abessynie).

Amérique du Nord: BRYCE, 1924 (N. Dakota, U.S.A.).

Amérique du Sud: MURRAY, 1923 (Brésil).

##### 5. *Brachionus plicatilis*.

Cette espèce était très rare dans notre échantillon 1; par contre, nous l'avons trouvée en grand nombre dans l'échantillon 14. Plusieurs individus portaient des oeufs, nous en avons même rencontré portant 2 ou 3 oeufs.

Données écologiques:

température le l'eau = 20,0° (le 22 avril 1957).

pH = 7,6 (id).

teneur en chlorures = 2,130 g/l (22 avril 1957) à 12, 200g/l. (15 oct. 1956).

Il s'agit ici d'une espèce marine et des eaux saumâtres. D'après HAUER (1925) elle est déjà rare à une teneur en chlorures de 15 g/l; elle a été trouvée en Westphalie dans des eaux à une teneur en chlorures d'environ 30 g/l. D'un autre côté cependant, HAUER (l.c., pg. 189) signale l'abondance de l'espèce dans d'autres échantillons avec des teneurs en chlorures de 6,30 et 1,40 g/l en moyenne. Il est donc très difficile de se fonder sur les données de HAUER. Nous avons encore des récoltes belges à Nieuport (CRÉ, 1951) avec 19 à 20 gr de chlore par litre et à une occasion exceptionnelle (cfr. CRÉ, l.c. pg. 4) de 1,34 gr: échantillon prélevé par marée basse. Si nous y comparons nos propres données, respectivement

2,130 g/l pour l'échantillon 1 et

12,200 g/l pour l'échantillon 14,

et en plus les données de LÖFFLER (1956), qui l'a trouvée en abondance dans deux lacs salés de l'Iran, ayant une teneur en chlorures respectivement de 3,895 et de 2,100 g/l, nous constatons que l'espèce supporte les eaux mésohalines aussi bien que les eaux polyhalines.

Distribution dans l'eau saumâtre:

a) en Europe:

France: DE BEAUCHAMP, 1932 (Haut-Rhin).

Belgique: CRÉ, 1951 (Nieuport).

Pays-Bas: WIBAUT, 1922 (Zuiderzee, Y à Amsterdam); REDEKE, 1935 (provinces de Noordholland et de Friesland); CRÉ, 1951 (Zee-land).

Allemagne: THIENEMANN, 1913 (Westphalie); HAUER, 1925 (Oldesloe); RENTZ, 1940 (Rügen); ALTHAUS, 1957 (Environs de Halle-Saale).

Iles Britanniques: HUDSON ET GOSSE, 1889 (Côtes du Devon, de l'Essex et du Norfolk, Firth of Tay.)

HOOD, 1895 (Côte ouest de l'Irlande).

Danemark: EHRENBERG, 1838 (environs de Copenhague).

Mer Baltique: MÖBIUS, 1874; LAUTERBORN, 1905; SICK 1933 (environs de Kiel).

Mer Adriatique: WULFERT, 1942 (Rovigno d'Istria).

U.R.S.S.: DECKSBACH, 1924 (embouchure des rivières dans la Mer Baltique, le Mer Noire et la Mer d'Azow; lac d'Aral, Russie centrale, Charkow).

b) hors de l'Europe:

Asie: VAVILOV, 1928 (Kamysch-Samara, Sibérie); EDMONDSON ET HUTSCHINSON, 1934 (Tibet); HADA, 1939 (Japon); LÖFFLER, 1956 (Iran); HAUER, 1957 (lac de Van, Turquie).

Afrique: BRYCE, 1931 (Abessynie); HUTCHINSON, 1932 (Afrique du Sud);

BEADLE, 1943 (Algérie française).

Amérique du Nord: MYERS, 1917 (Californie); BRYCE, 1924 (N. Dakota, U.S.A.);

RAWSON, 1944 (Saskatchewan, Canada central).

Amérique du Sud: MURRAY, 1913 (Brésil).

#### 6. *Notholca striata*.

*Notholca striata* était très commune dans l'échantillon 1 et rare dans l'échantillon 2.

Données écologiques:

température de l'eau = 20,0° à 21,0°.

pH — 7,6 à 8,6.

teneur en chlorures = 2,130 à 3,730 g/l.

C'est une espèce très largement répandue, qui est trouvée dans toutes les eaux douces, saumâtres et salées. On trouvera dans notre travail 1957, les raisons pour lesquelles nous considérons *Notholca squamula* (MÜLLER, 1786) comme synonyme de *Notholca striata* (MÜLLER), contrairement à CARLIN (1943) et GILLARD (1951).

Distribution dans l'eau saumâtre:

a) en Europe:

Belgique: CRÉ, 1949 (polders de l'Esacut); DE RIDDER, 1957 (Assenede).

Allemagne: HAUER, 1925 (Oldesloe); ALTHAUS, 1957 (environs de Halle-Saale).

Iles Britanniques: HOOD, 1895 (côte ouest de l'Irlande); GALLIFORD, 1945 (environs de Liverpool); id, 1948 (presqu'île de Wirral, Cheshire).

Danemark: EHRENBURG, 1838 (environs de Copenhague).  
 Côte Norvégienne: BERZINS, 1952.  
 Mer Baltique: EICHWALD, 1849 (Reval); LEVANDER, 1894 (Helsinki);  
 SICK, 1933 (Kiel).  
 Mer Adriatique: WULFERT, 1942 (Rovigno d'Istria).  
 b) hors de l'Europe:  
 Asie: HADA, 1939 (Japon); YAMAMOTO, 1953 (Corée).  
 Afrique: BEADLE, 1943 (Algérie française).  
 Amérique du Nord: BRYCE, 1924 (N. Dakota, U.S.A.); WAILLES, 1934  
 (Colombe Britannique) RAWSON, 1944 (Saskatchewan, Canada  
 Central).

### 7. *Notholca acuminata*.

Cette espèce n'était pas rare dans l'échantillon 1. De plus, nous  
 avons trouvé quelques exemplaires dans l'échantillon 10.

Données écologiques:

température de l'eau = 16,1° à 20,0°.

pH = 7,6 à 8,5.

teneur en chlorures = 2,130 g/l à 15,265 g/l.

Sa répartition et son écologie ne diffèrent pas sensiblement de cel-  
 les de *Notholca striata*.

Distribution dans l'eau saumâtre:

a) en Europe:

Belgique: LOPPENS, 1908, GILLARD, 1948 (Nieuport); VAN OYE, 1947,  
 GILLARD, 1948, DE RIDDER, 1957 (Assenede); GILLARD, 1948  
 (polders de la Flandre Orientale); CRÉ 1949 (polders de l'Escaut).  
 Pays-Bas: WIBAUT, 1922 (Zuiderzee); REDEKE, 1935 (provinces de  
 Noordholland et de Friesland).

Allemagne: HAUSER, 1925 (Oldesloe); ALTHAUS, 1957 (environs de  
 Halle-Saale).

Iles Britanniques: HUDSON ET GOSSE, 1889 (Côte du Devon, Firth  
 of Tay); GLASCOTT, 1893 (côte est de l'Irlande); HOOD, 1895  
 (côte ouest de l'Irlande); BRYCE, 1928 (Ecosse); GALLIFORD, 1945  
 (environs de Liverpool); id, 1948 (presqu'île de Wirral, Cheshire).

Mer Baltique; EHRENBURG, 1838, LAUTERBORN, 1905, SICK, 1933  
 (Kiel).

Côte norvégienne: LIE-PETTERSON, 1905; BERZINS, 1952).

Finlande: LEVANDER, 1901, VÄLIKANGAS, 1926 (environs de Helsinki).

Pologne: WULFERT, 1943 (Ciechocinek, vallée de la Weichsel).

Mer Adriatique: WULFERT, 1942 (Rovigno d'Istria).

Hongrie: NOGRADI, 1957 (environs de Fülöpzállás).

U.R.S.S.: DECKSBACH, 1924 (embouchure de la Petchora).

b) hors de l'Europe:

Asie: HADA, 1939 (Japon); YAMAMOTO, 1953 (Corée).

Afrique: BEADLE, 1943 (Algérie française).

Amérique du Nord: BRYCE, 1924 (N. Dakota, U.S.A.); WAILES, 1934 (Colombe Britannique); RAWSON, 1944 (Saskatchewan, Canada central).

#### 8. *Euchlanis dilatata*.

Encore une espèce trouvée dans un seul échantillon (1) et en petite quantité.

Données écologiques:

température de l'eau = 20,0°.

pH = 7,6.

teneur en chlorures = 2,130 g/l.

C'est une espèce très euryhaline, assez courante dans l'eau douce, et plus rare dans l'eau saumâtre et salée, que l'on connaît néanmoins de plusieurs localités côtières.

Distribution dans l'eau saumâtre:

a) en Europe:

Belgique: LOPPENS, 1098 (Nieuport); EVENS, 1954 (Hamme); DE RIDDER, 1957 (Assenede).

Pays-Bas: REDEKE, 1935 (provinces de Noordholland, Zuidholland et Friesland).

Allemagne: WULFERT, 1939 (Saale-Elster-Niederung); ALTHAUS, 1957 (environs de Halle-Saale).

Espagne: WISZNIEWSKI, 1931 (environs de Valence).

Mer Baltique: EICHWALD, 1849 (Reval).

Côte de la Finlande: LEVANDER, 1901, VÄLIKANGAS, 1926 (environs de Helsinki).

Hongrie: NOGRADI, 1957 (environs de Fülopszállás).

b) hors de l'Europe:

Asie: YAMAMOTO, 1953 (Corée); LÖFFLER, 1957 (Iran).

#### 9. *Lepadella patella*.

Nous n'avons trouvé cette espèce que dans l'échantillon 1, où elle était très abondante.

Données écologiques:

température de l'eau = 20,0°.

pH 7,6.

teneur en chlorures = 2,130 g/l.

Nos exemplaires mesuraient 78 à 85  $\mu$  en longueur et 60 à 64  $\mu$  en largeur. Ils correspondent donc à *Lepadella similis* (LUCKS, 1912), qui diffère de *L. patella* par l'ouverture pédale hexagonale et par une taille inférieure. HAUER, 1925, pg. 171—172, dit de *L. similis* que l'ouverture pédale n'est pas toujours nettement hexagonale. Ses exemplaires des eaux saumâtres d'Oldesloe étaient peu variables, tandis que

d'autres exemplaires provenant d'eaux douces présentaient une amplitude de variation beaucoup plus grande. Les dimensions qu'il donne varient entre 74 et 99  $\mu$  (longueur) et 58 et 78  $\mu$  (largeur). Il ajoute que cette forme est très voisine de *L. patella* que est toutefois plus grande; il donne les dimensions suivantes pour *L. patella* d'après HARRING:

longueur: 100 à 108  $\mu$   
largeur: 65 à 90  $\mu$ .

HARRING (1916) rapporte *L. similis* à *L. patella*, mais avec doute. REMANE (1929, e 115) dit que les deux formes sont reliées par de nombreux intermédiaires, de sorte qu'on ne peut considérer *L. similis* que comme une „variété” de *L. patella*.

Distribution dans l'eau saumâtre:

a) en Europe:

Belgique: LOPPENS, 1908 (Nieuport).

Allemagne: HAUER, 1925 (Oldesloe); REMANE, 1929 (Saspersee près de Dantzig).

Iles Britanniques: GALLIFORD, 1948 (Presqu'île de Wirral, Cheshire).

Espagne: WISZNIEWSKI, 1931 (environs de Valence).

Hongrie: NOGRADI, 1957 (environs de Fülopszállás).

U.R.S.S.: DECKSBACH, 1924 (Russie centrale).

Mer Adriatique: WULFERT, 1942 (Rovigno d'Istria).

b) hors de l'Europe:

Asie: YAMAMOTO, 1953 (Corée).

Afrique: BRYCE, 1931 (Abessynie).

Amérique du Nord: BRYCE, 1924 (N. Dakota, U.S.A.).

#### 10. *Colurella adriatica*.

Cette espèce était très commune dans nos échantillons 1 et 2.

Données écologiques:

température de l'eau = 20,0° à 21,0°.

pH = 7,6 à 8,6.

teneur en chlorures = 2,130 à 3,730 g/l.

Comme on sait, HAUER (1925) reconnaissait trois formes de *Colurella adriatica*, distinguées par la forme de la coque, par la taille et également par l'écologie. Nos exemplaires appartiennent à la forme  $\beta$  en ce qui concerne la forme de la carapace. Les dimensions sont cependant très grandes (122 à 130  $\mu$ ) chez les exemplaires mesurés. Ces dimensions surpassent même les chiffres donnés par HAUER pour les plus grandes, c.à.d.  $\gamma$  (99 à 114  $\mu$ ). Nous renvoyons le lecteur à notre article „Recherches sur les Rotifères des eaux saumâtres. II. „Le Zwin”, dans lequel nous signalons que la forme  $\alpha$ , trouvée à la côte belge (Zwin près de Knocke) dans une eau fortement

saline, se distinguait aussi par ses dimensions largement supérieures à celles données par HAUER.

La présente récolte semble appuyer notre supposition que *Colurella adriatica* atteint des dimensions plus grandes dans des milieux côtiers fort riches en chlorures et se trouvant en communication directe avec la mer.

Distribution dans l'eau saumâtre:

a) en Europe:

France: DE BEAUCHAMP, 1907 (St. Jean de Luz, Roscoff).

Belgique: DE RIDDER, sous presse (Zwin, Knocke).

Pays-Bas: WIBAUT, 1922 (Zuiderzee); REDEKE, 1935 (province de Noordholland).

Allemagne: HAUER, 1925 (Oldesloe); WULFERT, 1939 (Saale-Elster-Niederung); ALTHAUS, 1957 (environs de Halle-Saale).

Iles Britanniques: HUDSON ET GOSSE, 1889: côtes N et S. de l'Angleterre; GALLIFORD, 1945 (environs de Liverpool); id., 1948 (presqu'île de Wirral, Cheshire).

Mer Baltique: EHRENBERG, 1838; SICK, 1933 (environs de Kiel); Eichwald, 1849 (Reval).

Côte norvégienne: LIE-PETTERSON, 1905; BERZINS, 1952.

Côte de la Finlande: LEVANDER, 1901; VÄLIKANGAS, 1926.

Méditerranée: v. DADAY, 1890 (golfe de Naples).

Mer Adriatique: WULFERT, 1942 (Rovigno d'Istria).

Espagne: WISNIEWSKI, 1931 (environs de Valence).

Hongrie: NOGRADI, 1957 (environs de Fülopszállás).

b) hors de l'Europe:

Asie: HADA, 1939 (Japon); YAMAMOTO, 1953 (Corée); HAUER, 1957 (Turquie).

Amérique du Nord: Bryce, 1924 (N. Dakota, U.S.A.).

#### 11. *Colurella bicuspidata*.

Nous n'avons trouvé cette espèce que dans l'échantillon 1, en petite quantité.

Données écologiques:

température de l'eau = 20,0°.

pH = 7,6,

teneur en chlorures = 2,130 g/l.

Nos exemplaires ne présentaient aucune particularité. Pour une scission éventuelle du genre *Colurella*, fondée sur la présence ou l'absence d'une fente ventrale, nous renvoyons à l'article cité de ALTHAUS, pg. 130.

Distribution dans l'eau saumâtre:

a) Europe:

Allemagne: ALTHAUS, 1957 (environs de Halle-Saale).

Pologne: WULFERT, 1943 (Ciechocinek, vallée de la Weichsel).  
Côte norvégienne: LIE-PETTERSON, 1905.  
Mer Adriatique: WULFERT, 1942 (Rovigno d'Istria).

## 12. *Colurella colurus*.

*Colurella colurus* n'a été trouvée que dans l'échantillon 2 et s'y est montrée rare.

Données écologiques:

température de l'eau = 21,0°.

pH = 8,6.

teneur en chlorures = 3,730 g/l.

HAUER (l.c., pg. 177) reconnaît pour cette espèce également trois formes différentes. Nos exemplaires correspondent à sa forme *a*, mais sont nettement plus grandes (mensuration de HAUER: 96  $\mu$ , de ALTHAUS (1956): 92—101  $\mu$ , les nôtres aux environs de 105  $\mu$ ).

ALTHAUS (l.c., pg. 132) estime que malgré les différences qu'elle cite et étant donné la grande variabilité des *Colurella*, il vaudrait mieux considérer toutes les formes en question comme étant conspécifiques. C'est également notre opinion; pour le reste nous estimons que les différences entre les formes de *Colurella colurus* sont nettement moins marquées que celles constatées entre les formes de *C. adriatica*. Comme pour cette dernière espèce, nous croyons que la taille de *C. colurus* croît dans les biotopes côtiers.

Distribution dans l'eau saumâtre:

a) en Europe:

Belgique: EVENS, 1954 (Hamme).

DE RIDDER, 1957 (Assenede).

Allemagne: HAUER, 1925 (Oldesloe).

ALTHAUS, 1957 (environs de Halle-Saale).

Iles Britanniques: HUDSON ET GOSSE, 1889 (côte du Devon et du Forfarshire, Firth of Tay).

GLASCOTT, 1893 (côte est de l'Irlande).

HOOD, 1895 (côte ouest de l'Irlande).

Côte norvégienne: BERZINS, 1952.

Mer baltique: EHRENBERG, 1838, SICK 1933 (environs de Kiel).

EICHWALD, 1849 (environs de Reval).

Méditerranée: DUJARDIN, 1841; v. Daday, 1890 (golfe de Naples).

Mer adriatique: WULFERT, 1942 (Rovigno d'Istria).

b) hors de l'Europe:

Amérique du Nord: HARRING, 1921 (Martin's Point, Alaska).

BRYCE, 1924 (N. Dakota, U.S.A.).

MYERS, 1936 (New Jersey, U.S.A.).

13. *Lecane (Lecane) nana*.

Cette espèce a été trouvée dans notre échantillon 1, où elle était rarissime.

Données écologiques:

température de l'eau = 20,0°.

pH = 7,6.

teneur en chlorures = 2,130 g/l.

Nos exemplaires correspondent très bien à la figure et description de HAUER (1925, pg. 169, fig. 8) et à la figure d'ALTHAUS (1956, 38 f). La taille ne présente non plus aucune particularité.

On connaît cette espèce de tous les continents, tant des eaux douces que saumâtres. Les données étant toutes récentes et peu nombreuses, on peut se demander s'il s'agit dans tous les cas de la même espèce, et s'il ne s'agit par dans certains cas d'une action de la loi des séries homologues dans la variation. A noter que *Lecane nana* fut décrite par MURRAY en 1913 du lac andin Titicaca.

Distribution dans l'eau saumâtre:

Allemagne: HAUER, 1925 (Oldesloe, Saspersee près de Dantzig).

ALTHAUS, 1957 (environs de Halle-Saale).

14. *Testudinella clypeata*.

Trouvée dans les échantillons 8 et 12, et dans les deux rare à très rare.

Données écologiques:

température de l'eau = 16,1° à 27,1°.

pH = 8,4 à 8,5.

teneur en chlorures = 7,810 à 18,105 g/l.

Suivant les données de la littérature, surtout REMANE (1929, pg. 103), il s'agit d'une espèce en premier lieu marine. Sa présence dans un milieu côtier nous paraît donc assez naturelle. Nous l'avons trouvée également dans le milieu polyhalin du Zwin en Belgique, avec une teneur en chlorures de 10,880 à 25,550 g/l (DE RIDDER, sous presse).

Suivant DE BEAUCHAMP (1928), *T. clypeata* (MÜLLER) serait remplacée dans les eaux douces par *T. elliptica* (EHRBG.). Il serait donc intéressant de revoir les captures de *T. clypeata* dans les eaux douces.

Distribution dans l'eau saumâtre:

France: DE BEAUCHAMP, 1907 (St. Jean de Luz, Basses Pyrénées).

Belgique: DE RIDDER, sous presse (Zwin, Knocke).

Pays-Bas: WIBAUT, 1922 (Zuiderzee); GILLARD, 1947 (Zeeland).

REDEKE, 1935 (provinces de Noordholland et de Friesland).  
Iles Britanniques: HUDSON ET GOSSE, 1887 (côte du Devon et de l'Essex).

id., 1889 (Firth of Tay).

GLASCOTT, 1893 (côte est de l'Irlande).  
 HOOD, 1895 (côte est et ouest de l'Ecosse, côte ouest de l'Irlande).  
 BRYCE, 1928 (côte de l'Ecosse).  
 GALLIFORD, 1945 (environs de Liverpool).  
 id., 1948 (presqu'île de Wirral, Cheshire).  
 Danemark: EHRENBURG 1838 (environs de Copenhague).  
 Côte de la Finlande: LEVANDER, 1894.  
 Côte norvégienne: LIE-PETTERSON, 1908; BERZINS, 1952.  
 Mer Baltique: EHRENBURG, 1838, SICK, 1993 (port de Kiel).  
 Méditerranée: VON DADAY, 1890 (golfe de Naples).  
 Mer adriatique: WULFERT, 1942 (Rovigno d'Istria).

## RÉSUMÉ

Pour la première fois, les rotifères de la Camargue sont examinés. Des échantillons ont été pris aux environs de Salin de Badon, le long de la digue de mer et dans l'étang de Beauduc.

Les 15 espèces trouvées sont nouvelles pour la région. Pour chacune d'elles, nous donnons l'écologie et la distribution dans l'eau saumâtre dans le monde entier.

La plupart des espèces sont cosmopolites; une espèce est particulièrement intéressante, notamment *Epiphanes mollis*, dont c'est la première capture dans l'eau saumâtre de l'Europe occidentale.

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# Observations on the diatom flora of Braunton Burrows, N. Devon

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Braunton Burrows (Nat. Grid. Ref. 245135) is a complex system of sand dunes and slacks<sup>1)</sup> on the North Devon coast. The ridges are irregular and appear to arise from an aggregation of mobile parabolic dunes; low-lying slacks are enclosed by the ridges and landward of the high dunes is an extensive area of low relief with small sand-hills and blow-outs. This system is different from that of the Lancashire coast south of Southport, where the algal flora has been investigated by ROUND (in press), in that there, the dunes run in strictly parallel ridges alternating with elongated slacks. At Braunton Burrows the topography is such that drainage occurs by percolation through the sand in all directions except northwards, and the water table is domed. Water therefore does not tend to accumulate and remain in the slacks, so that although these may at times contain standing water, well developed aquatic communities and underwater soils such as are found on the Lancashire coast are not formed. However, a few poorly developed aquatic plants grow in the Braunton slacks and samples of these plants and of the sand were taken in order to compare the diatom flora of this rather dry slack system with that of the wetter system of Lancashire. Samples were also examined from the drier dune regions and from mosses growing on the dunes since no data exist for these algal communities in this country. A general account of the topography and vegetation of the Braunton dune system is given by WILLIS, FOLKES, HOPE-SIMPSON & YEMM (in prep.).

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<sup>1)</sup> These are large or small depressions between sand dunes; they may be dry and overgrown with higher plant vegetation or contain open water at least for part of the year.

## SAMPLES AND METHODS

In June 1956 thirty-one samples were collected from three habitat groups and are as follows: Aquatic-sediment from a drainage ditch (1) and *Chara* from an artificial water hole (2). Subject to seasonal flooding in wet years: seven samples of Hypnoid mosses (3—9), one of *Mentha aquatica* (10), one of *Anagallis tenella* (11), two of *Littorella uniflora* (12, 13) and nine sand samples from the slacks (14—22). Dry dunes: one sand sample (23), four of *Camptothecium lutescens* (24—27), three of *Tortula ruraliformis* (28—30) and one of *Tortella flavovirens* (31).

Nos. 10—13 are from very moist slacks where, for a part of the year, there is usually a shallow depth of water. The Hypnoid mosses, chiefly *Acrocladium cuspidatum* and *Drepanocladus aduncus*, come from damp regions where the higher plants are often a mixture, including *Salix repens*, *Juncus articulatus*, *Carex flacca*, *Agrostis stolonifera*, *Hydrocotyle vulgaris*, *Potentilla anserina* and *Pulicaria dysenterica* etc. The other moss samples all come from the drier dune slopes and it is unlikely that they are ever covered by water. With the exception of sample No. 23, and to a lesser extent No. 18, the sand samples were all from damp slack regions. Other samples of sand of dry dune, of *Ononis repens* growing on the dunes and of *Hydrocotyle vulgaris* growing in the slacks yielded no diatom species.

The samples were cleaned by boiling in a mixture of concentrated sulphuric and nitric acids, filtered, washed in distilled water, and mounted in Hyrax. Counts of 100 frustules were made on the prepared slides except in some of the more barren samples where this number could not be found. The remainder of the coverglasses were traversed and species not met in the counts recorded. The results are given in Table I. Except for some of the samples from the slacks the material was not rich in diatoms, although these, together with species of the Cyanophyceae, are the dominant algae.

### *The Flora*

Four types of diatom community can be recognised.

- (1) The community growing on the sediment of the wet ditch.
- (2) The damp sand community of the wet slacks and blow-outs.
- (3) The community growing amongst a thick cover of moist Hypnoid mosses on flat overgrown slacks and the communities epiphytic on Angiosperms. The *Chara* sample may also be included here although it was submerged, whereas the Angiosperms were exposed on the slack floor.
- (4) The community growing on the moss plants of dry dunes above flood level, i.e. on *Camptothecium lutescens*, *Tortula ruraliformis* and *Tortella flavovirens*.

(1) The sediment sample from the drainage channel is not as rich in species as might be expected from such a habitat. Only 24 were recorded. The dominants were *Synedra ulna* var. *biceps* and *Diploneis ovalis*. The former species was not recorded elsewhere on Braunton Burrows and is obviously a species which requires permanent water (see later discussion). Other species of importance are *Eunotia lunaris*, *Navicula cincta*, *N. oblonga*, *Pinnularia maior*, *Epithemia zebra* var. *porcellus* and *Nitzschia amphibia*.

(2) The damp sand community is dominated by *Epithemia* spp. probably consisting mainly of *E. zebra* var. *saxonica* in eight samples and by *Navicula radiosa* in one. The other species, in order of importance in this community are *Rhopalodia gibba* and var. *ventricosa*, *Diploneis ovalis*, *Nitzschia sinuata*, *Pinnularia viridis* and *Amphora ovalis* var. *libyca*. Less important are *Caloneis silicula*, *Navicula cincta*, *N. cryptocephala*, *N. radiosa*, *N. pygmaea*, *Mastogloia* spp. (in particular *M. smithii* var. *lacustris*), *Cymbella aequalis* and *Nitzschia amphibia*. In addition to the above, there are records, mainly of species of the Naviculaceae, scattered throughout the ten samples. The number of species in this community is very small, varying from 16—28 with an average of 21.

(3) In contrast to the group of mosses growing in dry situations, the hygrophytic Hypnoid mosses harbour a richer flora and in addition the three diatom species, which are so conspicuous amongst the dune mosses (see below) are here relatively unimportant. Both *Achnanthes coarctata* and *Pinnularia borealis* are present in one sample only, whilst *Hantzschia amphioxys* is present in 6 out of 7 samples but figures only once in the counts. The sample in which the *Achnanthes* and *Pinnularia* species were found is the only one of this group which had a sparse flora and on which no count was possible; field observations indicate that this was probably a very dry habitat for the Hypnoid mosses. The dominant species in all other samples is *Epithemia zebra* var. *saxonica*, and the subdominant *Rhopalodia gibba*. Other species of importance in this flora are *Navicula radiosa*, *Diploneis ovalis*, *Pinnularia viridis*, *Nitzschia sinuata* and *Nitzschia amphibia*. These are all species which were present in the damp sand community of the slacks.

*Eunotia lunaris*, *Navicula placentula*, *Navicula oblonga*, *Mastogloia smithii* var. *lacustris*, *Gomphonema intricatum* and *G. longiceps* var. *subclavata* fo. *gracilis* were also found. The number of species varies between 10 (the dry sample) and 25 — average 17, in these respects approaching the damp sand community and much richer than the dry moss.

The epiphytic algal flora of the Angiosperm samples is dominated by *Epithemia* and *Rhopalodia* species; *Mentha aquatica* is an excep-

tion, having an extremely sparse flora. Apart from the above, only *Navicula cincta*, *Mastogloia smithii* var. *lacustris* (see discussion), *Diploneis ovalis* and *Nitzschia sinuata* can be regarded as true components of this flora. The number of species in the community is small, 2—27, average 12 (or 15 if the *Mentha aquatica* sample is excluded).

The *Chara* sample possessed a sparse diatom flora which was completely dominated by *Rhopalodia gibba*, with *Achnanthes minutissima* var. *cryptocephala* as subdominant in the ratio of 10 : 1. The complete absence of *Epithemia* species is most striking.

(4) Species from the mosses growing on the dry dunes are few in number. Where counts were possible, the only species regularly recorded were *Achnanthes coarctata*, *Pinnularia borealis* and *Hantzschia amphioxys*. It is extremely difficult to obtain moss samples free of sand grains and some of the other species, few though they are, belong to other communities and may have been carried here by the wind together with the sand particles. However, *A. coarctata* var. *elliptica* was recorded only from this community, whilst *Navicula contenta* fo. *biceps*, *Diploneis ovalis* and *Amphora ovalis* are all probably members of this flora. In sample No. 16 *Epithemia* spp., probably *E. zebra* var. *saxonica* was abundant and even this must be regarded with suspicion, since one of the characteristic features of the other moss samples is the rarity of *Epithemia* spp. That sample 29 is contaminated is also suggested by the unusually large number of species found. *H. amphioxys*, although not always present, appears to dominate this community whenever it occurs, but it was not so conspicuous in the *Tortula ruraliformis* samples. The number of species (3—10) and the average number of species (7) are even lower than those of the damp sand community. Sample (23) of sand from this region shows the effect of dessication on the sand flora (compare with samples 16—22 from the slacks). The flora was so sparse that no count was possible.

## NOTES ON SOME SPECIES AND GROUPS

The diatoms in these samples all belong to the Pennales. The only species of the Centrales which might have been expected are *Melosira dickiei* and *M. rooseana* which are common epiphytes on mosses (BEGER, 1927 and ROUND, 1957). Their absence may be associated with the lack of dripping water which is usual in the moss communities in which they abound. BEGER (1927) does, however, state that *M. rooseana* is capable of withstanding considerable periods of drought.

*Araphidineae* are found on the damp sand (e.g. *Fragilaria intermedia*) but are more common in the aquatic habitats. *F. intermedia* is frequent in habitats of high base status. *Synedra ulna* var. *biceps* was more common in samples from slacks at Freshfield, Lancashire, (ROUND, in press) particularly in reed beds which were covered by water for most of the year, so that its restriction at Braunton to the more permanent water habitat is not surprising.

Only *Achnanthes* of the *Monoraphidineae* was found, being represented principally by *A. coarctata* and var. *elliptica*, which are almost confined to the dry dune moss habitat. These species were absent from the Bryophytes growing on sandstone in Brotherton Park, Cheshire. (ROUND, 1957) where instead the common aquatic species, *A. lanceolata*, was present. HUSTEDT (1930) records the habitat of this species as „dripping rocks”. However, BEGER’s (1927) and my observations on Bryophytes from dry areas show that *A. coarctata* is a characteristic species of such habitats.

Of the *Raphidioidineae* only *Eunotia lunaris* has been recorded and is most frequent in the truly aquatic habitat of the drainage ditch. This is one of the few *Eunotia* species of alkaline waters. Small species such as *E. exigua* and *E. tenella*, previously recorded from Bryophyte material, are absent presumably because the conditions in the moss communities at Braunton are too dry and also the pH may be too high.

Species of the *Biraphidineae* are very common. The single find of *Frustulia rhomboides* var. *saxonica* is almost certainly due to contamination since this variety is characteristic of acidic moorland/oligotrophic lake habitats. Likewise species such as *Stauroneis phoenicentron*, *S. smithii*, *Navicula bacillum*, *Pinnularia gentilis*, *P. mesolepta*, *P. gibba*, *Amphora veneta*, *Cymbella naviculiformis* and *Suriella tenera* are all either contaminants or are at the extremity of their ecological range requiring wetter conditions and in some instances lower pH. Only *Stauroneis phoenicentron* achieved any degree of abundance in the Freshfield slacks and then only at one station, whilst most of the others were absent or rare. The occurrence of *Neidium iridis* fo. *vernalis* is interesting since it was the only species of this genus present in the Freshfield slacks and was confined there to one sampling station. *Navicula halophila*, *N. grevillei* and *N. pygmaea* are widely distributed in slightly saline or marine habitats. Only *N. pygmaea* is at all conspicuous here and is more frequent than at Freshfield, the damp slacks favouring its development more than the aquatic habitat of Freshfield. I have found this species abundant on the estuarine sands of the River Dee, Cheshire, where it is covered twice a day by the tide and subjected to wide changes in salinity. In the damp Braunton slacks it is probably at the limit of its distribu-

tion due to lack of salt. The presence of species such as *Navicula binodis*, *N. dicephala*, *N. placentula* and *N. oblonga* are all indicative of the high base status of the habitats. *Mastogloia* species are rare in inland waters except for those of very high calcium content. At Freshfield species of this genus were found only as epiphytes on *Equisetum* and *Littorella*, whereas here they grow on *Littorella*, on the bare sand and amongst the moist Hypnoid moss communities. *Amphora ovalis* is inconspicuous compared with Freshfield, which is probably due to the drier nature of all the Braunton habitats. *Hantzschia amphioxys*, *Achnanthes coarctata* and *Pinnularia borealis* are characteristic of the dry moss community; however, only the first is widespread on the moist sand and amongst Hypnoid mosses. The wider range is in line with its extensive distribution on subaerial soils and relative absence on underwater ones. I have found *Nitzschia sinuata* only in extreme base rich waters. At Braunton it is common in the moist sand community but is also present amongst the Hypnoid mosses and on the Angiosperms where it may be a contaminant in the moist sand community but is also present amongst the Hypnoid mosses and on the Angiosperms where it may be a contaminant from the sand. It was not recorded at Freshfield which suggests that it is a subaerial species in these coastal dunes. *N. denticula* is often present in smaller numbers but only on the moist sand, whilst *N. amphibia*, although less common than *N. sinuata*, occurs in the same range of habitats. *Cymatopleura solea*, a predominantly aquatic species, occurs in the drainage channel and not in the moist slacks; at Freshfield *C. elliptica* was common but has not been recorded from Braunton.

## DISCUSSION

The only diatoms previously recorded from this dune system are *Amphora ovalis*, *Epithemia* spp. and *Navicula viridis* (now *Pinnularia viridis*) the latter said to be abundant (WATSON, 1918). The number of species now recorded from Braunton is approximately the same as that for the Freshfield region. Excluding those of the dry moss samples which belong to a community which was not included in the Freshfield analysis, the only important additions to the diatom flora of dunes are *Anomoconeis zellensis*, *Epithemia zebra* var. *saxonica* (*E. zebra* var. *porcellus* was the main *Epithemia* species at Freshfield), *Rhopalodia gibba* var. *vent icosia* and *Nitzschia sinuata*. The absence of these from Freshfield cannot be explained by the presence of standing water there since they are forms (with the possible exception of *Nitzschia sinuata*) which are common in lakes. The following were not found at Braunton but were common at Freshfield: *Navicula*

TABLE I

## HYPNOID MOSSES

[illegible]



*pupula* var. *capitata*, *N. pupula* var. *rectangularis*, *Cymatopleura elliptica*, *Nitzschia angustata*, *N. sigmoidea*, *Navicula baciliformis*, *Gomphonema acuminatum* and vars., *E. turgida* var. *granulata*. Their presence at Freshfield may be related to the pond-like conditions found in the slacks. The most common diatoms at Freshfield are *Navicula radiosa*, *Amphora ovalis*, *N. cryptocephala*, *N. dicephala* and *Cymatopleura elliptica*, the first three of these being the dominants. At Braunton *Navicula radiosa* and *Diploneis ovalis* are also fairly frequent but *Amphora ovalis* is not so abundant and the remaining species are rare or absent. At Braunton the species which are common at Freshfield are subdominant to *Epithemia zebra* var. *saxonica*, *Rhopalodia gibba* and var. *ventricosa* and *Nitzschia sinuata*. Thus it appears that due to the drier conditions in the Braunton slacks the *Navicula/Amphora/Diploneis* complex is displaced by an *Epithemia/Rhopalodia/Nitzschia* complex. *Epithemia* and *Rhopalodia* also occur at Freshfield but there they are virtually confined to the underwater epiphytic community.

The diatom community of the damp Hypnoid mosses at Braunton may be compared with that of the almost permanently submerged single *Hypnum* sample examined from Freshfield. *Epithemia* and *Rhopalodia* species are dominants in both. Further comparison of the floras shows that *Navicula radiosa*, *N. oblonga*, *Diploneis ovalis*, *Pinnularia viridis*, *Cymbella incerta*, *C. aspera*, *Gomphonema acuminatum* var. *coronata*, *Hantzschia amphioxys* var. *maior* and *Nitzschia amphibia* are present at Freshfield, and that these, or closely related forms, with the exception of *C. incerta* and the *Gomphonema* species, are all common in the drier Braunton samples. The rich diatom flora on these pleurocarpous mosses is very probably determined by the degree of moisture in the damp pastures since BEGER (1927) found the *Achnanthes/Pinnularia/Hantzschia* community amongst Hypnoid mosses of drier habitats. Unlike the flora on the mosses *Camptothecium/Tortula/Tortella* of the drier dune sides, the community on the damp Hypnoid mosses does not possess any distinctive species which are confined to it and in composition it approaches that of the damp slack sand. This is unlikely to be due to contamination since many of the Hypnoid moss samples were obtained from extensive damp pastures where no bare sand was visible. It differs from the damp sand community in the greater abundance of *Hantzschia amphioxys*, *Gomphonema* spp. *Navicula oblonga*, *N. placentula* and *Eunotia lunaris* and in the sparsity of *Caloneis silicula*, *Neidium iridis* fo. *vernalis*, *Navicula cryptocephala*, *N. pygmaea*, *Amphora ovalis* and *Cymbella aequalis*. Thus, although the dominant species are similar, the two communities as a whole show certain distinct differences. In comparison with the diatoms associated with Hypnoid

mosses in other habitats, the Braunton community is different in that *Tabellaria flocculosa*, *Meridion circulare*, *Fragilaria*, *Achnanthes*, *Cocconeis*, *Cymbella* and *Gomphonema* spp. are absent or infrequent.

The diatom flora of the Angiosperm samples shows a much larger variety of species at Braunton than at Freshfield. This is surprising since those at Freshfield were from an almost permanently submerged community (the water in the slack dried out only for a short period in mid-summer), whereas those at Braunton are exposed for much longer. The dominants, *Epithemia* and *Rhopalodia*, are, however, similar. As with the Hypnoid moss community, there is a noteworthy absence of some common epiphytic genera found on these plants when growing in other habitats. Although *Epithemia* and *Rhopalodia* grow as epiphytes in lakes, they are not then usually dominant, but when they grow as epilithophytes they are sometimes more abundant.

The diatom community of the dry dune mosses is similar to that found elsewhere and does not seem to be greatly affected by the high base status of the region. It is well defined, since it grows in a highly specialised habitat and a small number of highly selective species are found which hardly extend into the adjacent communities. The small number of taxa contrasts with records from Brotherton Park (Round, in press) and with those of BEGER (1927) and is undoubtedly related to desiccation. Of the three dominants, *Hantzschia amphioxys* is ubiquitous on soil (LUND, 1945) whilst *Achnanthes coarctata* occurs in and around springs and on dripping rock surfaces (HUSTEDT, 1930).

The community on the damp sand of the slacks is probably a specialised section of those found on soils. Comparison of this flora with that for calcareous soils (LUND, 1945) shows that, apart from *Navicula cincta*, *N. cryptocephala* and *Hantzschia amphioxys*, there is little similarity. Even these three species, or forms of these, are not abundant in the slacks, whereas they are in normal soils. Many other diatoms of calcareous soil are absent from the Braunton sands and conversely the *Epithemia*:*Rhopalodia*/*Diploneis* complex is absent from calcareous soils. Factors which may be responsible for these differences are, the physical nature of the sandy surface, the low content of organic matter and the presence of free water during the winter months and in wet years in the summer. There were no diatoms in samples taken from the drier parts where water-logging is unlikely, presumably because such sand drains and dries rapidly. The flora of the damp slack sand approaches that of an underwater soil, such as is found in permanently wet slacks. Species from the Braunton slacks also grow on pond and lake soils with the exception of the two dominant genera *Epithemia* and *Rhopalodia*. Their absence from underwater soils is probably related to silting since they are non-

motile forms; this is not an operative factor in the slacks. Even at Freshfield where silting was not extreme they were not common on the sediments but were abundant on plants, where again silting is not a factor of importance.

## SUMMARY

The diatom flora has been analysed in 31 samples from the dune area at Braunton Burrows. Samples have been examined from (a) aquatic habitats, (b) soil, plants and mosses subject to seasonal flooding and (c) sand and mosses from dry dunes. The diatom flora of all these has been discussed and compared with data from elsewhere.

## ACKNOWLEDGEMENTS

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# Les *Staurostrum* de la Gaspésie P. Q. Can.

par

le Frère IRÉNÉE-MARIE I.C.

Travail entrepris et subventionné par  
l'OFFICE de RECHERCHES PROVINCIALES du Ministère de  
l'Industrie et du Commerce de la Province de Québec.

Ce fut pour nous une surprise de constater qu'en une seule saison d'exploration, durant un intervalle de 10 jours de recherches, nous avons pu trouver 126 entités du groupe des *Staurostrum*, seulement six de moins que nous en ont fourni deux saisons d'herborisation intenses dans le sud du Québec.

Sur ce nombre, 62 espèces, 30 variétés et 5 formes sont identiques dans les deux régions, et la balance, 29 espèces, 19 variétés et 2 formes sont absentes de la région de Montréal, voire même du reste du Canada, ou étaient encore inconnues pour la Science.

Pour les entités déjà connues dans le Québec, nous ne donnons que les dimensions indispensables à leur identification. Pour les entités nouvelles au moins pour le Québec, nous ajoutons une description sommaire et une figure exacte que nous considérons comme souvent plus utile qu'une longue description.

## Abbreviations

L.: longueur totale;

l.: largeur totale;

Is.: largeur de l'isthme;

(sp): sans les appendices;

N.R: Nombre des rayons quand ils sont plus de 3;

N.S: des épines aux ext. des rayons.

Le chiffre entre parenthèses indique le nombre des pièces d'eau ou des lacs où la plante a été trouvée.

## *STAURASTRUM* Meyen (1829)

1. *S. aculeatum* (Ehr.) Men. F.D. p. 324, figs 7, 8, pl. 56. (7).

L.: 35—48 mu; l.: 50—58 mu; Is.: 13—16 mu.

2. *S. alternans* Ehr. F.D. p. 283, figs 2 & 4, pl. 46. (6).  
L.: 25—33 mu; l.: 23—32 mu; Is.: 8—12 mu.
3. *S. anatinum* Cooke & Wills. F.D. p. 312, fig. 9, pl. 47. (12).  
L.: 50—58 mu; l.: 80—95 mu; Is.: 10—12 mu; N.S.: 3.
4. *Var. longibrachiatum* W. et G. S. West, F.D. p. 313, fig. 2, pl. 54. (12).  
L.: 40—62 mu; l.: 74—86 mu; Is.: 10—12 mu; N.S.: 2—3
5. *Var. truncatum* W. West F.D. p. 312, fig. 4, pl. 54. (8).  
L.: 48—56 mu; l.: 80—98 mu; Is.: 16—20 mu; N.S.: 2—3.
6. *Var. curtum* G. M. Smith. F.D. p. 313, fig. 3, pl. 54. Lacs 12 & 30.  
L.: 28—35 mu; l.: 54—74 mu; Is.: 12—12.5 mu; N.S.: 2—3.
7. *S. ankyroides* Wolle. N.C. Vol. 78, No 10, p. 304, fig. 3, pl. 1.  
L.: 60—65 mu; l.: 119—130 mu; Is.: 11—12.5 mu.

Nous traduisons la diagnose de G. M. SMITH:

Grande cellule dont la longueur égale environ trois fois la largeur (sp), à constriction légère, aux sinus médians sous forme de dépressions semi-circulaires; isthme large, hémisomate à base cylindrique légèrement enflée près de l'isthme et au sommet, lequel se prolonge en 4 appendices, ceux d'un hémisomate alternant avec ceux de l'autre, les appendices fortement convergents, leur marge supérieure dentelée plus visiblement que l'inférieure; la base des appendices, jusqu'à leur milieu ornée d'épines bifides et aplaties, et du milieu jusqu'au bout, d'épines simples diminuant graduellement jusqu'à l'extrémité; l'extrémité de l'appendice est armée de 3 petites épines. Le sommet de l'hémisomate porte 4 verrues émarginées insérées entre les appendices. La vue apicale est quadrangulaire, les angles se prolongent en longs et gracieux appendices terminés par 3 petites épines, la base des appendices, ornée de longues verrues bifides, et le reste des appendices orné d'épines simples. L'axe de chaque appendice porte un rang d'épines simples, et le corps de la cellule, une verrue arquée à mi-chemin entre chaque paire d'appendices. Fig. 20.

8. *S. Anchora* W. et G. S. West. Wisconsin Phytoplankton p. 101.  
Lac No 22.

Grande cellule deux fois plus longue que large, à constriction légère, aux sinus presque semi-circulaires, à l'isthme large, à l'hémisomate légèrement campanulé. Les sommets sont droits, prolongés de chaque côté en un appendice atténué graduellement, terminé par 3 épines fines et divergentes, les marges extérieures faiblement crénelées par une dizaine de verrues arquées. La vue apicale est elliptique, portant à l'intérieur des marges une dizaine de granules arqués, et se prolongeant aux pôles par un long appendice atténué, granuleux, terminé par 3 épines fines et aiguës.

L.: 65—88 mu; l.: 140—155 mu; Is.: 13—14 mu; Epaisseur: 23—24 mu.

Cette espèce n'est pas sans affinité avec *S. bicornis* Hauptfl. Elle

s'en distingue par ses appendices plus déliés et ses sinus plus largement ouverts. Première mention pour le Canada. Fig. 1.

9. *S. arachnae* Ralfs, F.D. p. 322, fig. 10, pl. 54. (4).

L.: 26—28 mu; l.: 40—54 mu; Is.: 8—9.5 mu.

10. *S. Arcticon* (Ehr.) Lund. F.D. p. 334, fig. 2, pl. 57. (5).

L.: 100—145 mu; l.: 90—125 mu; Is.: 23—30 mu; long. app.: 30—35 mu.

11. *Var. glabrum* W. et G. S. West F.D. p. 334, fig. 3, pl. 57 et fig. 6, pl. 59.

L.: 105—125 mu; l.: 107—120 mu; Is.: 25—26 mu; long. app.: 30—33 mu; Lacs 12 et 27.

12. *Var. truncatum* I.—M. F.D. p. 335, fig. 1, pl. 57. Lacs 12 & 27.

L.: 115—125 mu; l.: 110—120 mu; Is.: 23—26 mu.

13. *S. affine* W. et G. S. West. F.D. p. 305, fig. 3, pl. 49.

L.: 36—41 mu; l.: 43—55 mu; Is.: 10.5—11 mu; Lacs Nos 26 & 41.

14. *S. aphis* I.—M. Hydr. Vol. IV, No 1, p. 55, fig. 5, pl. 1.

L.: 12—13 mu; l.: 14.5—15 mu; Is.: 4 mu. (Lac No 7).

15. *S. apiculatum* Bréb. F.D. p. 277, figs 13—15, pl. 45.

L.: 30—31 mu; l.: 27—27.5 mu; Is.: 6 mu; Epines: 3—3.5 mu. (7)

16. *S. Avicula* Bréb. N.C. Vol. 78, No 9, p. 307, fig. 4

L.: 25—28 mu; l.: 30—36 mu; Is.: 10—12.5 mu. Lacs 16 et 30.

17. *Var. subarcuatum* (Wolle) W. West. F.D. p. 286, figs. 5,8, pl. 50.

L.: 26—28 mu; l.: 31—36 mu; Is.: 11—13 mu. Lacs Nos 16, 27, 30.

18. *S. bicornis* Hauptfl. N.C. Vol. 81, No 11, p. 299, fig. 37, pl. IV.

L.: 51.5 mu; l.: 70—74 mu; Is.: 13—13.5 mu. (5).

Espèce assez proche de *S. Anchora* W. et W. Voir ci-dessus No 8.

Deuxième mention pour la Canada. Fig. 21.

19. *S. bioculatum* W. R. Taylor. N.C. Vol. 78, No 10, p. 308, fig. 5, pl. 1.

L.: 70—75 mu; l.: 92—97 mu; Is.: 10—11.5 mu.

20. *S. brachiatum* Ralfs. F.D. p. 298, fig. 11, pl. 53.

L.: 25—35 mu; l.: 39—45.5 mu; Is.: 11.5—12 mu. (7).

Nous n'avons trouvé que des spécimens triangulaires. Cette espèce, sous sa forme triangulaire est commune dans toute la Province de Québec..

21. *S. brasiliense* Ndt. Monog. Brit. Desm. Vol. 5, p. 35, fig. 11, pl. CXXXV.

L.: 80—83.5 mu; l.: 85—90 mu; Is.: 32—32.5 mu; Epines: 15—25 mu. (Lac 45).

Grande cellule environ une fois et un tiers plus longue que large, à constriction profonde, aux sinus larges, hémisomate cunéiforme et court, au sommet légèrement rétus et à marge apicale concave. Cha-

que angle du sommet se termine par trois fortes épines divergentes. La membrane est ponctuée: L'isthme mesure environ la moitié du diamètre de la cellule. La vue apicale peut avoir 4 ou 5 côtés, chaque sommet terminé par 3 épines divergentes. D'après les WEST (Monog. Vol. V, p. 35).

Nous n'avons trouvé en Gaspésie que les formes à 3 et à 5 côtés. Figs 2, 3, 4. Première mention pour le Canada.

22. *Var. Lundellii* W. et G. S. West. N.C. Vol. 76, No 12, p. 300, fig. 12. pl. V.

L.: 150—160 mu; l.: 141—150 mu; Is.: 30—31 mu. Lac No 45.

23. *S. Brebisonii*. Arch. *var. brevispinum* West. F.D. p. 294, fig. 4, pl. 51.

L.: 49 mu; l.: 45—46 mu; Is.: 16—17.5 mu. Lacs Nos 36, 45.

24. *S. breviaculeatum* G. M. Smith. F.D. p. 292, fig. 3. pl. 51.

L.: 37—45 mu; l.: 38—53 mu; Is.: 9.5—12.5 mu; Ep.: 4—6 mu. (6).

25. *S. brevispinum* Brèb. *forma major* W. et G. S. West.

F.D. p. 271, Fig. 6, pl. 48.

L.: 74 mu; l.: 88.5 mu; Is.: 48 mu. (6).

Le corps de la plante varie peu; les mucrons sont bien développés, et convergent légèrement vers l'isthme. Cette forme est plutôt rare, et n'a été signalée que 2 fois dans la Province de Québec.

26. *S. caronense* I.—M. N.C. Vol. 76, No 3, p. 103, fig. 3, pl. 1. (6).

L.: 35.5—37 mu; l.: 35.5—37 mu; Is.: 10 mu.

Deuxième mention pour la Province.

27. *S. Cerastes* Lund. Hydr. Vol. IV, No 1, pp. 61—63. Etude.

L.: 48.5 mu—54 mu; l.: 50—65 mu; Is.: 11.5—14 mu. Lacs 40, 48.

Dans la région, la forme triangulaire est plus commune que la forme quadrangulaire. La base est cyathiforme et les appendices sont plus verruqueux que chez la forme quadrangulaire. Assez souvent, à l'opposé de ce que nous avons constaté au Lac-St-Jean, les dimensions de la forme triangulaire sont inférieures à celles de la forme rectangulaire. Ainsi, les dimensions prises sur 10 spécimens triangulaires sont comprises dans les limites suivantes:

L.: 40.5—54.8 mu; l.: 53—65.5 mu; larg. à la base: 10.5—16 mu; Is.: 9.7—10.5 mu.

28. *S. connatum* (Lund). Roy & Biss. F.D. p. 277, fig. 7, pl. 45. (8).

L. (ss): 21—34 mu; l.: 21—23.5 mu; Is.: 6—6.5 mu; Epines: 10—13 mu.

29. *S. conspicuum* W. et G. S. West F.D. p. 270, fig. 4, pl. 45.

L.: 60—100 mu; l.: 108—125 mu; Is.: 20—25 mu; Membrane ponctuée. (6).

30. *S. cornutum* Arch. F.D. p. 289, fig. 3, pl. 50. (Lac No 48).

L.: 30—33 mu; l.: 29—32 mu; Is.: 11—12 mu; Long. des Epines: 6—7 mu.

31. *Var. biradiatum* I.—M. F.D. p. 289, fig. 3, pl. 50. Lac No 48.  
L.: 32—35 mu; l.: 30—33 mu; Is.: 11—12.5 mu; Epaisseur: 3—5 mu.
32. *S. crenulatum* (Nag.) Delp. F.D. p. 323, fig. 11, pl. 47; f. 17, pl. 49.  
L.: 23—26 mu; l.: 23—34 mu; Is.: 6—7.5 mu. Lacs Nos 1 & 8.
33. *S. cruciatum* Wolle: Desm. of the United States p. 156 figs. 11—13, pl. LVI.  
L. (ss): 20—23 mu; l. (ss): 20—23.5 mu; Is.: 7—8 mu; Soies: 3—4 mu.

Nous donnons ici ce que nous croyons être l'espèce *S. cruciatum* Wolle, mais sans en avoir la certitude. La description du „Vieux Maître” nous semble meilleure que ses dessins. Voici comment il décrit l'espèce:

„Petite cellule lisse, vue frontale cruciforme, lobes courts, linéaires, aux extrémités arrondies, aux sinus larges, rectangulaires; vue apicale 3-lobée ou 4-lobée, légèrement atténuée, extrémités arrondies, et portant un certain nombre de soies (poils longs et fins) divergentes, aussi longues que le lobe. Diamètre: 25 mu sans les soies.” Nous ne voyons pas bien comment entendre „Vue apicale 3-4-lobés”. Nos spécimens sont elliptiques.

Première mention de cette espèce depuis sa description, il y a plus de 65 ans. Nous l'avons trouvée dans les lacs Nos 30 et 33. Fig. 5.

34. *S. curvatum* West. Monog. Brit. Desm. Vol. V, p. 19, ff. 15, 16, Pl. CXXX.

L.(ss): 26—33 mu; l.:(ss) 21—26 mu; (cs): 72—76 mu; longueur des épines: 21—24 mu; Is.: 5.5—8 mu. Lacs No 28, et 46.

Cellule de moyenne dimension, légèrement plus longue que large (ss), à constriction profonde, aux sinus presque rectangulaires, aigus-arrondis au fond. L'hémisomate est triangulaire, prolongé par de longs appendices divergents. Le sommet est concave et lisse. La vue apicale est triangulaire aux marges un peu concaves, se prolongeant aux angles en une longue épine. La membrane est lisse. Le chloroplaste est axillaire, avec un pyrénioïde central, et un lobe du protoplasme s'étendant vers les angles jusqu'à la naissance des épines. Cette espèce n'avait encore été signalée qu'une fois au Canada, par G. H. WAILES, pour la Colombie Canadienne (1930). Fig. 6.

35. *Var. elongatum* G. M. Smith: Wiscons. Phytoplankton Part II, p. 75, figs 10—15, pl. 69, Lacs Nos 8 et 46.

Cellule dont l'isthme est allongé et cylindrique, et la courbure des sommets plus prononcée que chez le type. La vue apicale montre les côtés plus rétus. Les dimensions sont sensiblement celles du type:

L.: 25—30 mu (ss); l.: 25—53 mu (ss); Long. des épines: 9—15 mu.

Cette variété est aussi rare que le type. G. M. SMITH l'a trouvée dans le Wisconsin avant que nous la repérions dans la Gaspésie. Fig. 6.

36. *S. cuspidatum* Bréb. F.D. p. 280, figs 1, 2, pl. 55.

L. (ss): 22—26 mu; l.: 16—23 mu; Is.: 5—6 mu; Epines: 8—12 mu. (6).

37. *Var. divergens* Ndt. F.D. p. 280, fig. 14, pl. 49. (7).

L. (ss): 20—23.5 mu; l.: 20—22 mu; Is.: 5—6.5 mu; Epines: 20—23.5 mu.

38. *Var. canadense* G. M. Smith. N.C. Vol. 78, No 9. fig. 10, pl. I. (4).

L.: 38—39 mu; l. (ss): 26—31.5 mu; Is.: 5—5.5 mu; Epines: 17.5—19 mu.

39. *S. cyrtocerum* Bréb. F.D. p. 307, figs 9 & 13, pl. 49.

L.: 32—39 mu; l.: 42—49 mu; Is.: 11—12 mu. (Lacs Nos 1 & 29).

40. *S. dejectum* Bréb. F.D. p. 278, fig. 11, pl. 45 (16).

L.: (ss): 23—25 mu; l.: 24—26.5 mu; Is.: 6.5—7 mu; Long. épi. 7—8 mu.

41. *S. Dickiei* Ralfs. F.D. p. 275. fig. 10, pl. 44.

L. 38—45 mu; l.: 45—58 mu; Is.: 6—11 mu. Lacs Nos 30 & 31

42. *Var. circulare* Turn. F.D. p. 276, fig. 1, pl. 50.

L.: 40—43 mu; l.: 40—44 mu; Is.: 13—14 mu. (5).

43. *Var. maximum* W. et G. S. West. F.D. p. 275, fig. 11, pl. 44; fig. 2, pl. 47.

L.: 46—67 mu; l.: 65—82 mu; Is.: 11—15 mu. Lac No 20.

44. *Var. rhomboideum* W. et G. S. West F.D. p. 275, fig. 56, pl. 46; f. 4, pl. 47.

L.: 36—45 mu; l. (ss): 40—47.5 mu; (cs): 52—69 mu; Is.: 10—12.5 mu. (4).

45. *forma depressum* I.-M. F.D. p. 276, fig. 3, pl. 55.

L.: 27.5 mu; l.: 64.5 mu; (ss): 44 mu; Is.: 13.5 mu. Lac No 30.

46. *S. dilatatum* Ehr. F.D. p. 284, figs 10 & 11, pl. 46; f. 8, pl. 48.

L.: 21—30 mu; l.: 20—27.5 mu; Is.: 9—12 mu. Forme quadrang. Lacs Nos 1, 6, 7.

47. *Var. hibernicum* W. et G. S. West. Monog. Brit. Desm. Vol. 4, p. 175, fig. 18, pl. 126.

L.: 25 mu; l.: 22—25.5 mu; Is.: 7.5 mu. Lacs Nos 7 et 31.

Cette variété est nouvelle pour le Québec. Elle a été mentionnée pour notre Province du Labrador par Cedercreutz en 1942. Fig. 8.

48. *S. disputatum* W. et G. S. West, *Var. extensum* (Borge) W. et G. S. West.

Monog. Brit. Desm. Vol. IV, p. 177, fig. 17, pl. CXXVI. Lac No 26.

Petite cellule un peu plus longue que large, à constriction très faible, sinus médians réduits à des encoches aiguës au fond, mais largement ouvertes; hémisomate largement cunéiforme, partant d'une base large et droite. (Chez le type, les bases sont convexes). Les marges latérales sont légèrement rétuses; les angles, arrondis et légèrement prolongés. La vue apicale est quadrangulaire, les angles arrondis et plus prolongés que chez le type. La membrane est granuleuse aux angles, mais le reste du corps de la cellule et le sommet sont lisses. Les granules sont disposés en 4 ou 5 anneaux autour des angles. Fig. 9.

49. *S. erasum* Bréb. N.C. Vol. 76, No 3, p. 109, fig. 8, pl. 1.

L.: 39—41 mu; l.: 38.5—46 mu; Is.: 13—15.5 mu. Lac No 7.

50. *S. excavatum* W. et G. S. West Desm. of Madagascar: Linn. Soc. Second Ser. Bot. Vol. V, p. 41—91. Lac No 32.

Nous traduisons ici la diagnose des WEST:

„Petit *Stecurastrum* 3 fois plus large que long (avec les appendices) à constriction profonde, aux sinus ouverts et obtus; l'hémisomate est largement campanulé, les sommets sont profondément creusés, les angles supérieurs se prolongent en longs appendices droits, divergents, ondulés et atténués graduellement jusqu'aux extrémités, lesquelles se terminent par 3 petites épines. La vue apicale est fusiforme; les deux pôles prolongés par des appendices légèrement coubés et lisses.

L.: 15 mu; l. 46 mu; (sp): circ. 12 mu; Is.: 4.5 mu; Epais.: 6 mu”.

Cette espèce diffère des formes alliées par ses appendices très développés, par ses sommets profondément creusés en demi-cercle, et par sa vue apicale fusiforme. Elle ressemble un peu à *S. paradoxum* Meyen var. *longipes* W. B. Turner (Non Nordstedt). Elle se rapproche de *S. Coderrii* I.-M.: Hydrob. Vol. IV, No 1, p. 64, mais s'en distingue par ses dimensions, par le nombre des ondulations des appendices et le nombre des épines aux extrémités des appendices.

L.: 25.8—29 mu; (sp): 11.3—13 mu; l.: 29—40 mu; (sp): 9.7—11.3 mu; Is.: 5.6—6.5 mu. Fig. 10.

51. *S. franconicum* Reinsch. F.D. p. 316, fig. 10, pl. 73. Lac No 8.

L.: 19—22.5 mu; (sp): 14—15.5 mu; l.: 11—12.5 mu; Is.: 10—12.5 mu.

52. *S. frangens* I.-M. Hydrob. Vol. IV, No 1, p. 65, fig. 2, pl. VI.

L.: 23—24.5 mu; l.: 21.5—22.5 mu; Is.: 4—5 mu. Lac No 6.

53. *S. furcatum* (Ehr.) Bréb. F.D. p. 328, fig. 7, pl. 48.

L.: 28—35 mu; l.: 23—30 mu; Is.: 9.5—9.8 mu. Lacs Nos 3 & 39.

54. *Var. spinatum* I.-M. Hydr. Vol. IV, No 1, p. 71. fig. 6 & 7, pl. VII.

L.: 30—35 mu; l.: 24—33.5 mu; Is.: 10 mu; long. épines angulaires: 10 mu.

Deuxième mention de cette variété, décrite pour la région du

- Lac-St-Jean, dans Hydrob. en 1952. Lac No 39.
55. *S. furcigerum* Bréb. F.D. p. 331, figs 3—5, pl. 58. (10).  
L.: 56—70 mu; (ss): 30—45 mu; l.: 48—69 mu; (ss): 28—39 mu;  
Is.: 13—18 mu.
  56. *Var. armigerum* Ndt. F.D. p. 331, figs 4, 7, pl. 58. (4).  
L.: 48—57 mu; l.: 52—59 mu; Is.: 12—15.5 mu; append.: 20—  
25 mu.
  57. *Forma eustephana* (Ehr.) Ndt. F.D. p. 331. fig. 3, pl. 59. Lacs 3,  
16, 48  
L.: 40—56 mu; l.: 46—52.5 mu; Is.: 12—15.5 mu. Append. 18—  
22 mu.
  58. *S. glabrum* (Ehr.) Ralfs. F.D. p. 278, figs 6, 7, pl. 53. Lac No 8.  
L.: 20—24 mu; l. (ss): 20—23 mu; Is.: 9.5—10 mu; Epines: 7.5—  
8 mu.
  59. *S. gladiosum* Turn. F.D. p. 292, fig. 2, pl. 51.  
L.: 48—52 mu; l.: 44—51 mu; Is.: 10—12 mu; Epines: 3—5 mu.  
Lac No 8.
  60. *S. gracile* Ralfs. F.D. p. 313, fig. 13, pl. 48.  
L.: 28—60 mu; l.: 45—100 mu; Is.: 8—12 mu. (Dans 3 lacs).
  61. *Var nanum* Wille. F.D. p. 314, figs 12 & 15, pl. 49.  
L.: 15—24 mu; l.: 24—26 mu; Is.: 5—7.3 mu. Lac No 16.
  62. *S. grallatorium* Ndt. *var. forcipigerum* Lagern. F.D. p. 300, fig.  
6, pl. 52; fig. 8, pl. 53.  
L.: 50—54 mu; l.: 45—85 mu; Is.: 7.5—8.5 mu; Epines: 11—15  
mu. Lac No 12.
  63. *S. grande* Bulnh. N.C. Vol. 78, No 10, p. 320, fig. 5, pl. II.  
L.: 87—96 mu l.: 85—100 mu; Is. 21—25 mu. Lacs Nos 16 & 17.
  64. *Var. parvum* West F.D. p. 272, fig. 8, pl. 44, fig. 4, pl. 45.  
L.: 60—63 mu; l.: 57—51 mu; Is.: 13—14 mu. Lacs Nos 3, 7, 16.
  65. *Var. rotundatum* W. et G. S. West. F.D. p. 272, fig. 9, l  
L.: 70—78 mu; l.: 65—72 mu; Is.: 17—21 mu. Lacs Nos 21, 24.
  66. *S. hexacerum* (Ehr.) Wittr. F.D. p. 305, fig. 3, pl. 48.  
L.: 25—27 mu; l.: 31—35 mu; Is.: 7—7.5 mu (11 lacs).
  67. *S. illusum* W. et G. S. West, forma major, I.-M. N.C. Vol. 76,  
No 5, p. 114. Fig. 12, pl. I.  
L.: 33 mu; l.: 35 mu; Is.: 12 mu.  
Exactement les dimensions des spécimens de la région des Trois-  
Rivières. N.C. Vol. 76, p. 114. Lac No 8.
  68. *S. incospicuum* Ndt. F.D. p. 297, fig. 1, pl. 49.  
L.: 15—18 mu; l.: 15—17 mu; Is.: 6.5—7 mu. Lac No 48.
  69. *S. inflexum* Bréb. F.D. p. 304, figs 7 & 8, pl. 49.  
L.: 21—25 mu; l.: 31—41 mu; Is.: 5—7.5 mu. Lacs Nos 26 & 31.
  70. *S. iotanum* Wolle F.D. p. 301, figs 11—20, pl. 49.  
L.: 13—21 mu; l.: 13—21.5 mu; Is.: 4—5 mu. (5 lacs).

71. *S. leptacanthum* Ndt. F.D. p. 333, figs 1 & 2, pl. 48; 10 & 11, pl. 58.  
L.: 44—85 mu; l.: 54—68 mu; Is.: 11—13.5 mu. Lac No 12.
72. *S. leptocladum* Bdt. F.D. p. 289, fig. 4, pl. 53.  
L.: 57—95 mu; l.: 100—110 mu; Is.: 5—7.5 mu. Lacs Nos 3 & 16
73. *Var. sinuatum* Wolle, *forma planum* G. M. Smith F.D. p. 299, fig. 5, pl. 53.  
L.: 60—85 mu; l.: 80—110 mu; Is.: 8.5—9 mu Lac No 8.
74. *S. lunatum* Ralfs, F.D. p. 288, figs 9 & 10, pl. 50.  
L.: 30—39 mu; l.: 28—41 mu; Is.: 7—10 mu. Lacs Nos 2, 31.
75. *Var. planctonicum* W. et G. S. West F.D. p. 288, fig. 6, pl. 50.  
L.: 33—43 mu; l.: (ss) 37—48; Is.: 14—18 mu; Ep. 3.5—5 mu.  
Lac No 6.
76. *S. maamense* Arch. F.D. p. 289, fig. 6, pl. 51.  
L.: 34—37 mu; l.: 28—33 mu; Is.: 12—13 mu. (8).
77. *Forma atypicum* Magnotta (Notes on Michigan Desmids etc, p. 164.)  
Première mention depuis sa description en 1935. Lac No 32.  
Variété qui se distingue du type par les angles de la base qui sont armés d'une épine fine et aiguë.  
Les dimensions sont celles du type et le contour de l'hémisomate est également typique, à la différence du dernier segment, à la base, qui se prolonge en une épine fine et aiguë, de 6—7.5 mu de longueur. Fig. 11.
78. *S. Manfeldtii* Delp. F.D. 309, fig. 4, pl. 48.  
L.: 37—43 mu; l.: 53.5—56 mu; Is.: 10—12 mu. Lacs Nos 26 et 31.
79. *S. margaritaceum* (Ehr.) Men. F.D. p. 320, fig. 10, pl. 47; figs. 13 et 14, pl. 54.  
L.: 27—35 mu; l.: 26—37 mu; Is.: 8—13 mu. (5).
80. *S. megacanthum* Lund. F.D. p. 279, fig. 2, pl. 50. Lacs Nos 16 & 20.  
L.: 30—46 mu; l. (ss): 35—49 mu; Is.: 9—12 mu; Epines: 11—16 mu.
81. *S. Meriani* Reinsch. F.D. p. 268, fig. 1, pl. 45.  
L.: 36—45 mu; l.: 20—25 mu; Is.: 13—17.5 mu. Lac No 38.
82. *S. minnesotense* Wolle F.D. p. 280, figs 1 & 2, pl. 52.  
L.: 100—145 mu; l.: 120—150 mu; Is.: 20—32 mu. Lacs Nos 21 et 43.
83. *S. minutissimum* (Auersw. Reinsch. Monog. Brit. Desm. Vol. IV, p. 130, Fig. 2, pl. 119. Lac No 39.

Petite cellule un peu plus longue que large, à constriction très faible et à sinus très largement ouverts. La forme générale de l'hémisomate est quadrangulaire, les côtés presque droits, le sommet ondulé. La vue apicale est pentagonale ou tétragonale, (très rarement

triangulaire: W. et G. S. WEST) les côtés concaves et les sommets arrondis. La membrane est lisse.

L.: 8—12 mu; l.: 7—9 mu; Is.: 7—8 mu.

Les WEST prétendent à bon droit que l'espèce doit être considérée d'après les dessins de REINSCH et la figure 2, pl. 119 de leur Monographie, qui est une copie exacte du dessin de REINSCH. Il y a actuellement tant de formes différentes que l'on rapporte à l'espèce de AUERSWALD, qu'il a été nécessaire de recourir au type de cet auteur. C'est ce qu'ont fait les WEST, en examinant RABENHORST Alg. Europ. 1883, No 1828 (c fig.). De sorte que la seule espèce valide portant le nom de *S. minutissimum* (Auersw) Reinsch est celle qui a été figurée et décrite par REINSCH en 1867; REINSCH est la seule autorité pour cette espèce et toute espèce portant le nom de *S. minutissimum* demeure douteuse, comme toutes les figures publiées depuis 1867, si elle s'écarte notablement des figures de REINSCH. Première mention pour le Québec. Fig. 12, 13.

84. *S. muricatum* Bréb. N.C. Vol. 76, No 3, p. 118, fig. 3, pl. II.

L.: 55—50 mu; l.: 43—46 mu; Is.: 13—14.5 mu. Lacs Nos 6 et 33.

85. *S. muticum* Bréb. F.D. p. 303, fig. 6, pl. 56.

L.: 19.5—22.5 mu; l.: 17.6—21 mu; Is.: 6.5 mu. Lac No 30.

Cette espèce particulièrement commune au nord du fleuve semble une rareté en Gaspésie.

86. *S. Novae Cesarae* Wolle Hydr. Vol. IV, No 1, p. 82, fig. 4, pl. VIII.

L.: 67.5—75 mu; l.: 45—62 mu; Is.: 17—19 mu; Epines 11—12 mu;

Les spécimens de cette région sont en général moins grands que ceux de la région du Lac-St-Jean. Troisième mention de l'espèce pour l'Amérique du Nord. Lac No 36.

87. *S. Novae Terrae* W. R. Taylor. Hydr. Vol. IV, No 2, p. 83, fig. 5, pl. VIII.

L.: 35—45 mu; l.: 43—48 mu; Is.: 8—9.5 mu. Epines: 10 mu. Lac No 30.

88. *S. Novae Terrae* W. R. Taylor, var. *Taylorii* I.-M. Hydrob. Vol. IV, No 1, p. 83, fig. 6, pl. VIII.

L.: 35 mu; l.: 43—44.5 mu; Is.: 7.5—8 mu; Ep. 5—6 mu. (Lacs 30 & 32).

89. *Forma evoluta* I.-M. Hydr. Vol. IV, No 1, p. 84, fig. 7, pl. VIII.

L.: 32—33 mu; l.: 42.5—44 mu; Is.: 8.5—9.5 mu. (Lac No 32).

90. *S. Ophiura* Lund. F.D. p. 320, fig. 4, pl. 57.

L.: 65—85 mu; l.: 124—135 mu; Is.: 15—18.5 mu. (Lacs Nos 3 & 7).

91. *S. orbiculare* Ralfs. F.D. p. 275, fig. 10, pl. 45.

L.: 47—54 mu; l.: 44—47 mu; Is.: 13—15 mu. (10 Lacs).

92. *Var. depressum* Roy & Biss. Hydr. Vol. IV, No 1, pl. 85, fig. 9, pl. 8.

L.: 26—26.5 mu; l.: 24—24.5 mu; Is.: 9.6—9.8 mu. (Lac No 16).

93. *Var. Ralfsii* W. et G. S. West. Monog. Brit. Desm. Vol. IV, p. 156.

L.: 60—60.5 mu; l.: 49.5—50 mu; Is.: 18—18.3 mu; (Lacs Nos 41 & 48).

Cette variété que les WEST ont découverte près de Bowness, Westmorland, semble bien être la belle plante que nous avons récoltée dans les lacs 41 et 48. Sa forme extérieure est celle de *St. orbiculare f. major*. Mais les WEST ne croient pas devoir accepter cette *forma major* West de l'espèce *St. orbiculare*. „We have ourselves invariably, although erroneously, recorded it as such. Its most important character is the elevated apex of the semicell, giving the latter a triangular outline” Monog. Vol. IV, p. 157. Cependant, SOCHI HORI de l'université de Gunma Japon, accepte la *forma major* W. comme une entité différente de la *Var. Ralfsii* W. et W. Malheureusement, il ne donne pas de dimension pour ses spécimens. Fig. 14.

94. *Var. minor* Reinsch (Not G. W. Prescott, in Algae of Gatun Lake: 1936).

L.: 30—31 mu; l.: 28—28.5 mu; Ls.: 8.3—8.5 mu. Lacs Nos 3, 16, 29.

95. *S. paradoxum* Meyen F.D. p. 301, figs 11, 12, pl. 48; fig. 1, pl. 54.

L.: 35—40 mu; l.: 50—70 mu; Is.: 7.5—11 mu. (18).

96. *S. pentacerum* (Wolle) G. M. Smith F.D. p. 315, figs 1 & 15, pl. 56.

L.: 37—45 mu; l.: 84—105 mu; Is.: 11—13 mu. (Lacs Nos 12 et 21).

97. *S. pilosum* Arch. F.D. p. 294, fig. 7, pl. 51. (6 lacs).

L.: 46—48 mu; l.: 38—48 mu; Is.: 11—11.5 mu. Epines: 2—2.5 mu.

98. *S. polymorphum* Bréb. F.D. p. 306, fig. 7, pl. 47; ff. 4, 5, pl. 49; f. 4, pl. 55.

L.: 20—30 mu; l.: 22—40 mu; Is.: 6—9 mu. (Dans 15 lacs).

99. *Var. simplex*. W. et G. S. West N.C. Vol. LXXVI, No 3, p. 121, f. 5, pl. II.

Cellule relativement plus longue que le type (sans les append.). Les appendices sont presque horizontaux, et possèdent un cercle de granules près de l'extrémité; et chaque appendice est terminé par 4 petites épines. La membrane est lisse partout ailleurs. La vue apicale est quadrangulaire, les côtés droits ou légèrement concaves.

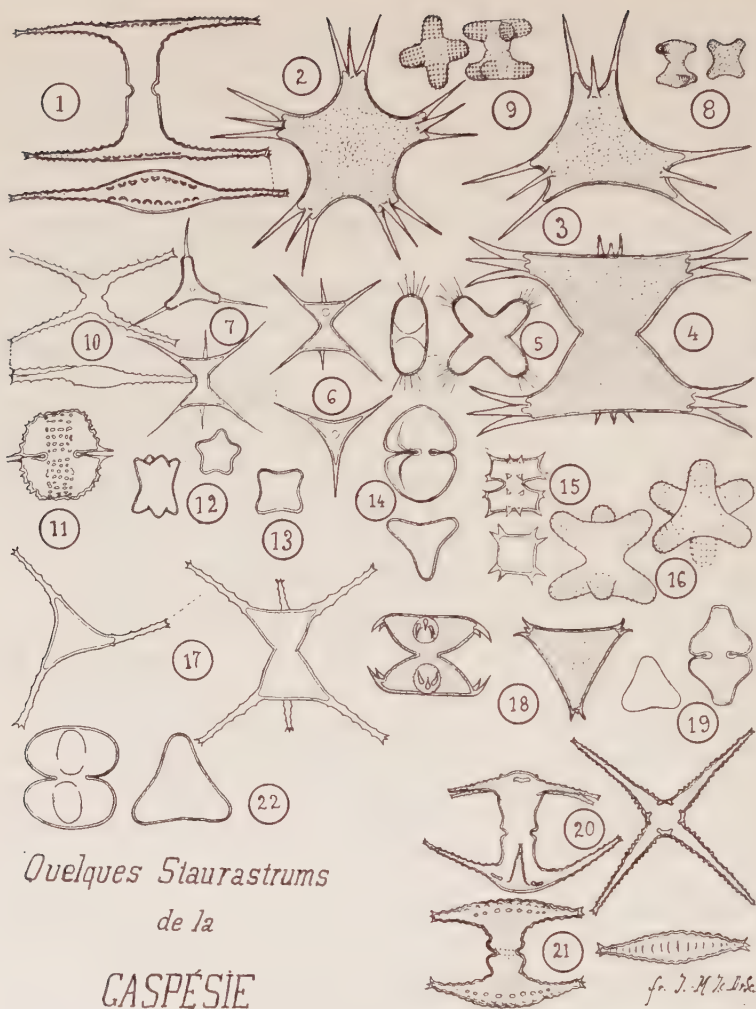
L.: (sp): 21.5—23 mu; l.: (sp) 13—15.5 mu; Is.: 7.5—7.8 mu; Appendices: (cs): 3.5—5 mu. Lac No 21.

100. *S. protectum* W. et G. S. West *var. planctonicum* G. M. Smith F.D. p. 310, Fig. 9, pl. 53.

- L.: 33—35 mu; l.: 41—49 mu; Is.: 7.5—8 mu; Epines: 7—9 mu.  
(Dans 4 lacs).
101. *S. Pseudosebaldi* Wille F.D. p. 308, fig. 9, pl. 54.  
L.: 51—53 mu; l.: 60—64.5 mu; Is.: 12—13.5 mu. Lacs Nos 31 & 48.
102. *S. quadrangulare* Bréb. Monog. Brit. Desm. Vol. V, p. 37, fig. 5, pl. 134.  
Petite cellule rectangulaire, aux sinus médians profonds, largement ouverts et aigus au fond, aux sommets droits ou presque, aux marges latérales droites ou légèrement concaves, aux marges ventrales droites ou légèrement convexes; les 4 angles de l'hémisomate sont armés chacun de 4 épines courtes et coniques, deux vers le sommet et deux vers la base, celles du sommet dirigées vers le haut, celles de la base vers l'isthme. En vue apicale, les épines de chaque angle se projettent les unes sur les autres. Les côtés sont droits ou un peu concaves, au nombre de 3—5 (WEST). Les spécimens récoltés en Gaspésie sont rectangulaires ou rarement triangulaires. Fig. 15.  
L.: 23—26 mu; l.: 23—26.5 mu; Is.: 8—10.5 mu. Lacs Nos 18 & 45.
103. *S. quebecense* I.-M. F.D. p. 306, fig. 6, pl. 47, fig. 5, pl. 54.  
L.: 40—44 mu; l.: 64—76 mu; Is.: 10—10.5 mu. (Dans 9 lacs).
104. *S. Ravenelli* Wood, var. *spinulosum* I.-M. F.D. p. 290, figs 12—15, pl. 56.  
L.: 34—35.5 mu; l.: 40—45 mu; Is.: 7—10.5 mu. Epines 3—5 mu. Lac No 47.
105. *S. Rotula* F.D. p. 323, fig. 6, pl. 57.  
L.: 41—45 mu; l.: 75—98 mu; Is.: 10.5—12.5 mu. Lacs Nos 12 & 48.
106. *S. Sebaldi* Reinsch. F.D. p. 308, figs 6, 8, pl. 54.  
L.: 70—85 mu; l.: 68—105 mu; Is.: 19—23 mu. (Dans 6 lacs).
107. Var. *ornatum* Ndt. F.D. p. 309, fig. 7, pl. 54.  
L.: 56—83 mu; l.: 89—125 mu; Is.: 16—22.5 mu. (Dans 4 lacs).
108. *S. setigerum* Cleve. F.D. p. 293, figs 11 & 12, pl. 50.  
L.: 49—55 mu; l.: 46—48 mu; Is.: 18—20 mu; Epines: 8—12 mu. (Dans 5 lacs).
109. Var. *pectinatum* W. et G. S. West. F.D. p. 294, fig. 1, pl. 51.  
L.: 57—60 mu; l.: 59.5—65 mu; Is.: 13—15.5 mu. Lac No 26.
110. *S. sexcostatum* Bréb. Var. *productum* W. West. F.D. p. 322, fig. 10, pl. 48.  
L.: 37—43 mu; l.: 41—41.5 mu; Is.: 13—14.5 mu. Lac No 1.
111. *S. Simonyi* Heimerl. F.D. p. 287, figs 8 & 12, pl. 46.  
L.: 22—25 mu; l.: 22—25 mu; Is.: 6.5—9.5 mu. Lac No 2.
112. *S. spiculiferum* G. M. Smith. F.D. p. 282, fig. 8, pl. 34; fig. 4, pl. 50.

- L.: 36—44 mu; l.: 35—43 mu; Is.: 7—8.5 mu. Lacs Nos 27, 30, 45.
113. *S. spongiosum* Bréb. F.D. p. 291, fig. 8, pl. 51.  
L.: 50—56 mu; l.: 43—56 mu; Is.: 15—18 mu. Lacs Nos 30, 31, 34,
114. *S. striolatum* (Nag.) Arch. var. *divergens* W. et G. S. West. Monog. Brit. Desm. Vol. IV, p. 178. Lac No 16.  
L.: 16—17.5 mu; l.: 16.7—18 mu; Is.: 5.5—6 mu.
- Variété un peu plus petite que le type; le sommet de l'hémisomate concave, les angles faiblement dilatés, un peu capités, et faiblement divergents, les sommets d'un hémisomate alternant avec ceux de l'autre. Jusqu'à date, cette variété n'avait encore été trouvée que dans l'Ile de Ceylan. Fig. 16.
115. *S. subgracillimum* W. et G. S. West Hydrob. Vol. IV, No 1, p. 95, fig. 5, pl. IX.  
L.: 10; l.: 42—50 mu; Is.: 5—5.6 mu. Lacs Nos 7, 8, 12.
116. *S. sublaevispinum* W. West. F.D. p. 297, fig. 2, pl. 49.  
L.: 21—25 mu; l.: 29—35 mu; Is.: 7—8 mu. Lac No 8.
117. *S. subscabrum* Ndt. F.D. p. 296, fig. 5, pl. 51.  
L.: 32—37 mu; l.: 32—39 mu; Is.: 10—13.5 mu. Lacs Nos 12 & 22.
118. *S. tenuissimum* W. et G. S. West. Desm. of Madagascar (1896), p. 37, Fig. 43, pl. VIII Lac 32.  
L. (sp): 10—10.5 mu; l (sp): 9.6—10 mu; (cp): 30.5—34 mu.  
Is.: 3—3.5 mu.
- Très petite plante, à peu près aussi longue que large (sans les appendices), à constriction profonde; l'isthme est obsemicirculaire, les sommets légèrement concaves, les angles supérieurs prolongés en appendices longs, ténus-courbés, divergents et légèrement ondulés, aux sommets tridenticulés. La vue apicale est triangulaire, les côtés presque droits, les angles prolongés en appendices très déliés, terminés par 3 petites épines. La membrane est lisse. Cette espèce, décrite pour Madagascar (1894) a été retrouvée par les WEST dans une récolte de L. N. JOHNSON (1898) en provenance de la Nouvelle-Angleterre. Première mention pour le Canada. A échelle double des autres dessins de la Planche. Fig. 17.
119. *S. tetracerum* Ralfs. F.D. p. 300, figs 16 & 19, pl. 49.  
L.: 22—30 mu; l.: 18—25 mu; Is.: 4—5 mu. Lacs Nos 17 & 39.
120. *S. tohopekaligense* Wolle. Hydr. Vol. IV. No 1. fig. 9, pl. IX.  
L.: 60—70 mu; l.: 58—70 mu; Is.: 14—15.5 mu; app. 16—18 mu  
Lac No 48.
121. *Var. brevispinum* G. M. Smith. F.D. p. 327, figs 6, 9, pl. 58.  
L.: 40—45 mu; l.: 35—38 mu; Is.: 13—13.5 mu; App.: 7—8 mu. Lac No 48.

122. *Var. nonnanum* Turn. F.D. p. 327, fig. 15, pl. 55.  
L.: 44—63 mu; l.: 45—69 mu; Is.: 16—18.5 mu. Lac No 48.
123. *S. trifidum* Ndt. Vidensk. Medel. 1869, p. 226, t, 4, fig. 51, *forma*, pl. 16. figures 20 et 21.  
L.: 30—32 mu; l. (ss): 32—36.5 mu; (cs); 44—50 mu; Is.: 10—12 mu.
- Petite plante à hémisomate vaguement elliptique, les sommets terminés par 3 épines courtes et aiguës. Sinus largement ouverts, légèrement arrondis au fond. Vue apicale triangulaire, les trois côtés peu creusés, réunis aux angles en un sommet tronqué bifide, surmonté d'une épine médiane. La membrane est finement ponctuée. Les dimensions de nos spécimens sont les suivantes:  
L.: 29—30 mu; l. (ss): 29; long. des épines: 12.5—13 mu; Is.: 12.8 mu.
- Cette espèce est nouvelle pour le Canada. Mais la variété suivante est connue depuis 1951, dans la région de Québec. (N.C. Vol. LXXVIII No 10), et dans celle des Trois-Rivières (1949) et du lac-St-Jean (N.C. Vol. LXX, No 1, p. 12, figs 9 & 10, pl. III). Fig. 18.
124. *Var. inflexum* W. et G. S. West. N.C. Vol. 76, No 3, p. 126, fig. 9, pl. II.  
L.: 30—40 mu; l.: 39.5—42.5 mu; Is.: 10—12.5 mu. Lacs Nos 3, 45, 49.
125. *S. trihedrale* Wolle. N.C. Vol. 76, No 3, p. 126, fig. 12, pl. II.  
L.: 43.—46 mu; l.: 30—32 mu; Is.: 12—12.5 mu. Lac No 3. Fig. 19.
126. *S. vestitum* Ralfs. F.D. p. 325, fig. 3, pl. 56.  
L.: 34—39 mu; l.: 45—70 mu; Is.: 10—12.5 mu. (5).



# The Inverted Microscope Method of Estimating Algal Numbers and the Statistical Basis of Estimations by Counting

by

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With 5 tables and 4 figures in the text.

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## I INTRODUCTION

The present communication concerns the estimation of algal populations by counting. There is no one method of estimating them which is the best under all circumstances and for all purposes. There are limits to the accuracy of any method, and, if they are not known, it is impossible to decide the value to be placed on any quantitative result. One limit is set by the equipment used, for example, if weighing is necessary, by the accuracy of the balance and weights. Other limiting factors come under the heading of experimental errors. The word "error" is perhaps unfortunate since it suggests a mistake, for example using the wrong kind of equipment or the right kind in the wrong manner. The word is, however, used by statisticians to cover the chance variations inherent in any method and includes variations arising from the procedures involved in collecting and treating a sample before an estimation is made. In the statistical section the errors of both types are evaluated.

A great advantage of counting is that there is no doubt how many organisms or cells are present within certain computable limits and degrees of chance (p. 154). The troublesome errors arising from the presence of extraneous matter when, for example, the dry weight or amount of pigment present are estimated do not arise, nor, if a suitable technique is used, are there any errors arising from the necessity of concentrating the material. So far, no alga is known which cannot be sedimented. Standardisation is at once achieved so that a worker can compare his results with anyone else's. Another advantage is that, since the cells are examined on each occasion, any changes in them are at once apparent. There is always the possibility of using these counts as a basis for other determinations. Once populations of sufficient size and purity have been collected in nature or produced in the laboratory, and weighing and chemical analyses done, it is possible to make estimates of the amounts of material in populations which are so small or so admixed with other species that direct ana-

lysis is impossible. The substances present are, of course, likely to vary to a greater or lesser degree according to the conditions, but probable upper and lower limits can be inferred. Further, as knowledge increases, these limits can be estimated with greater accuracy. Where the elementary composition varies but little under most if not all conditions, such data are relatively easily obtained. Examples, as have been mentioned, are the amount of silicon in many diatoms and carbon in most algae. Indeed if any variation in amount is much below 100 %, then clearly this is of little importance in studies on the changes in the size of a population, for every cell generation involves a change of 100 % in numbers, and very often in weight. It may be argued that multiplication may lead to no increase in matter. For example, a cell of a coccoid alga may produce sixteen autospores, each one approximately one sixteenth the size of the parent cell, but before these produce a further sixteen cells (or a lesser number) they are likely to have reached nearly or exactly the size of their parent cell. Thus comparison can be made from one generation to the next. This may only apply during a period of exponential growth, but similar basic data can be obtained for other stages in growth by the method of counting. It may also be argued that there are other cases where given increases in cell numbers are not paralleled by equal increases in cell matter. Diatoms, which often form an important part of a plankton community, furnish an example of this. Most diatoms show a more or less regular decrease in cell size during multiplication but, in nature at least, this is partly compensated for by the formation of auxospores. However, even if auxospores are not formed, as is often the case in cultures, the change in mean size is generally insignificant over the number of generations usually involved in an experiment. There is no obvious reason why other such difficulties cannot also be overcome.

Disadvantages of the method are often said to be the time taken to make counts, the fact that statistical procedures are only applicable to entities and not to their constituent parts (e.g. to colonies but not to their cells), that the laws of chance are such that little reliance can be placed on the count, and that the cells of algae vary so greatly in size. No method is perfect, but from what has been said, and from a consideration of the method to be described and its statistical basis, it will be seen that these disadvantages are not so great as might be imagined. They need only be considered shortly at this point. Counting need not be tedious, as large counts are unnecessary. Since, as has been said, we are generally concerned with the number of cell generations produced, we are dealing with changes of 100 %. Therefore counting need only be done in many cases to ensure that the probable range within which the true number lies is within  $\pm 50$  %.

Since the accuracy varies indirectly with the square root of the number of units counted, anything but a large increase in counts over the minimum necessary to achieve a probability of less than  $\pm 50\%$  is of little value. A count of one hundred algae takes only a few minutes at the most. With practice and the use of a little common sense it should never exceed five minutes for any one organism. A count of this number has a good chance of being within  $\pm 20\%$  of the true figure and a still better one of being within  $\pm 30\%$  (p. 155). It may still be argued that these are only chances and little confidence can be placed on a single count. That this is incorrect will be clear from p. 157 and table I, from which it can be seen that the likelihood of such a count being far outside these limits is exceedingly small, indeed there is only about one chance in a million that it will exceed  $\pm 50\%$  of the true value. It would, of course, take a long time to count all the species in a sample from nature to this degree of accuracy, but when there is such a need, various methods are available, the best for most purposes being the estimation of the amount of chlorophyll *a* or other pigments present. A review of this and other methods can be found in LUND & TALLING (1957). The best method for estimating a crop of diverse algae may well be to combine counting with one of the other methods mentioned. Evidence is given here (p. 167) to show that, in some cases at least, the errors arising from multiplying the number of organisms by the mean number of their constituent cells are so well within those inherent in the counting method that it is possible to determine the increase of cells in a population. There are algae, such as colonial Myxophyceae, which contain so many cells that it is impossible to determine the mean number per organism. It is, however, often possible to break up these algae into their constituent cells (p. 150), which are then separate entities. We have here, however, two sources of counting error, because it is necessary to find out how many colonies are present as well as how many cells (see p. 157). The variation in size and therefore of matter in cells of different algae are difficulties which cannot be overcome directly but, as has been explained, with present and future knowledge of the chemical composition, cell counts of one alga can be related to those of others in terms other than mere numbers.

Various kinds of chambers are in use into which the algae are put for counting, such as the haematocytometer, Sedgewick-Rafter, Naumann and Kolkwitz cells. UTERMÖHL (1927, 1931a, 1931b, 1936) has surveyed the principle methods and it is his technique, using an inverted microscope, which is here described. In general this is only suitable for the larger algae, and most nannoplankton forms are better counted in the chambers referred to or others which are constructed on the same principles. There is then no need to use an inverted mi-

roscope though this can be done with models more elaborate than the one described, (e.g. the UTERMÖHL inverted microscope marketed by Carl Zeiss, Oberkochen Wuerth, Germany). The statistical consideration of counting applies equally to all these methods.

## II INVERTED MICROSCOPE TECHNIQUE

### 1. *The Microscope*

A model marketed by W. R. Prior and Co. Ltd., London, England has been used, not because this is the best model but because, at the time this investigation began, it was the only model available to us. Other firms also market models of varying complexity and price which are probably now widely available. The mirror supplied is discarded and, to the vertical adjustable rod to which it was attached, is fused a metal tube about 0.6 m high, within which lies the electric light flex passing to a 60 or 100 watt opal lamp at the top. This light is fixed vertically above the opening for the objectives in the microscope stage. Its intensity can be varied by means of a resistance in the circuit. The whole can be moved about 15 cm up or down. A metal slide (approx. 7.5 cm long and 4 cm broad around the central orifice) is fixed between the metal clips of the mechanical stage. This slide has a central orifice 3.5 cm in diameter with a marginal flange 1 mm wide and 2 mm deep so that a nest of three rings may be fitted into it. Each type of sedimentation tube is fitted with a glass base of suitable

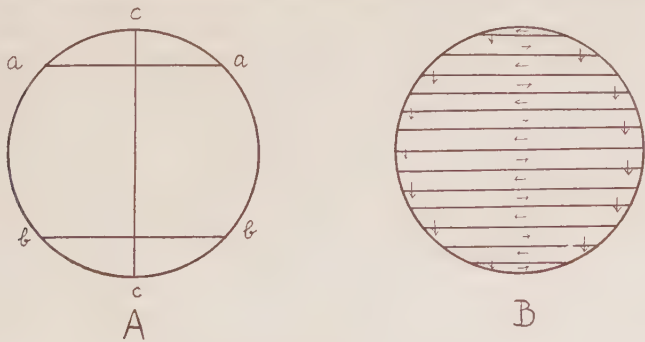


Figure 1. Method of counting.

A. Field of view down the microscope. All the algae lying between the two parallel hairs (a, b) are counted as they pass the vertical hair (c) through the movement of the mechanical stage.

B. The whole area of the base of the sedimentation tube is covered by traversing backwards and forwards as indicated, the mechanical stage being so moved when each traverse is concluded that hair a of Figure 1A occupies the position held by hair b or vice versa.

diameter to fit one of the rings. A 16 mm objective is used. It is also possible to use one of 4 mm but definition is poor and with this it takes a considerable time to scan the underside of the floor of even the smaller sedimentation tubes. A x10 or x12 ocular is used though one of lesser magnification can be substituted for counting the largest algae or smaller crustacea, rotifers etc. and, if desired, an objective of lower magnification as well. Three hairs are fixed in the ocular (fig. 1), two parallel and a convenient distance apart and the third perpendicular to them and placed so that it lies approximately in the middle of the field of view. The "hairs" are made and inserted as follows. A disc of thin cardboard of such size that it will lie on the metal flange within the ocular is cut out. The cross hairs are made by heating glass rod and pulling it out to form very fine threads. Pieces of these are affixed to the cardboard in the positions described above with blobs of gum, the free ends being broken off when the gum has dried.

## *2. Sedimentation Tubes*

The sedimentation tubes are cut from ordinary glass tubing. One end is ground flat and either a coverglass or glass disc, of somewhat greater diameter, is sealed on to it. Glass discs of similar thickness to a microscope slide have the advantage of not breaking easily and the disadvantage of only permitting the use of 16 mm objectives. The best cement for fixing them to the tubes is Araldite\* which can be obtained from Aero Research Ltd., Duxford, Cambs., England. This is supplied in sticks and full instructions for its use are given with them. However, for our purpose, it is best to powder some in a mortar and apply this in a thick slurry with water to the disc, pressing the ground end of the glass tube upon it. A further amount of slurry is now brushed around the outside of the join between tube and disc. The whole is placed in an oven for a given time at one of the temperatures recommended by the makers on their sheet of instructions. The sedimentation tube is allowed to cool and cleaning mixture (conc.  $\text{H}_2\text{SO}_4$  and  $\text{K}_2\text{Cr}_2\text{O}_7$ ) poured into the tube to remove the excess Araldite within. The length of time for the cleaning process depends on the amount of Araldite to be removed but a little practice will develop the necessary judgment. It is best to err on too short a time, since, otherwise, the cleaning mixture will attack the Araldite seal. Therefore, after a short time, the cleaning mixture is run off and the

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\* Recently a liquid form of Araldite (Araldite 103 and Hardener 951) has been put on the market and preliminary tests suggest that it is as good as the solid type.

ease of removal of any excess Araldite with a triangular needle or narrow spatula tested. If this is still difficult the cleaning is repeated. Cleaning may be carried out at room temperature or the tube may be placed on a warm hot plate to speed up the process. After the tube has been washed thoroughly to remove all traces of acid, it is ready for use. If it has been properly made, the seal will be so strong that the disc can hardly be removed from the tube without breaking the glass. Therefore, all tubes are best tested before use by attempts to pull off the disc by hand. In addition, the tube can be filled with water and left standing. If the seal has been attacked by too thorough cleaning, some will leak out.

In the absence of Araldite and the equipment for utilising it, polystyrene cement can be used though the join so made is weaker. On the other hand the process is so simple that repairs or renewals can be quickly effected. The cement is made up as follows: 15 g of polystyrene (commonly sold under the trade name of Distrene) is dissolved in 30 ml of xylene to which is added 5 ml of dibutylphthalate as a plasticizer (commercial butylphthalate is suitable). The solution may be thickened by evaporation or thinned with xylene. The ground end of the tube and basal disc are thoroughly coated with it, pressed together and left to dry at room temperature. Rapid drying by heating is possible but a harder film is produced. This is both less easy to remove from inside the tube and less adhesive. At room temperature, 12—24 hrs should be allowed for drying, after which a further coating is brushed round the outside of the join between tube and disc. The excess cement inside the tube is removed as follows. The tube is filled with water to which a drop of iodine solution (see below) is added to stain the polystyrene. After a few hours the water is poured out. The polystyrene now has a somewhat rubbery consistency. Pricking round the outer edge of the stained polystyrene with a needle will loosen it so that it can then be pulled off with a pair of forceps.

The height of the sedimentation tubes is a matter of convenience. We use tubes of approximately the following dimensions, the widest being used when an alga in small abundance is to be counted in the presence of others in greater abundance:— 2.5 by 1, 5 by 1, 3 by 1.5, 6.5 by 1.5, 5 by 2 cm.

### *3. Sedimentation Procedure*

The density of the population may be such that dilution or concentration in a long glass tube (e.g. Nessler) will be necessary before transference to the sedimentation tube. A saturated solution of iodine

in potassium iodide (Lugol's solution) is added, about 1 drop to 10 ml or 0.5 ml to 100 ml of water. This kills, stains and weights the algae, the majority being preserved in a recognisable state. This, of course, presupposes familiarity with freshwater algae. Great accuracy in the proportion of iodine to water is unnecessary but, if too little is added, all the algae may not be sedimented, for example the gas vacuoles of Myxophyceae are not discharged in very dilute iodine solution. If too much is added, examination on the microscope will be difficult, though this fault is easily cured by the addition of potassium thio-sulphate. Lugol's has been found to be the best solution. So far as is known no algae are destroyed by it. Formalin destroys delicate flagellates and does not discharge the gas vacuoles of Myxophyceae. It is occasionally of value to add but little iodine in order to disintegrate colonies of flagellates, such as *Uroglena*, where such large numbers of cells are present that counting them in the colonies is impracticable. Cells of some colonial algae can be separated by pre-treatment, for example boiling in water (*Coelosphaerium naegelianum*) or weak acids (some palmelloid green algae). In other cases the number of cells per colony can be reduced from many to few by similar treatments. Sometimes, when the iodine reagent is added, crystals of iodine are formed; the addition of some more potassium iodide to the stock solution will cure this trouble. It is very unlikely that other precipitates will appear but if they do concentrated HCl can be added, even in large amount.

The time allowed to ensure sedimentation of all the algae will vary with the depth of the column of liquid, but, using Nessler and sedimentation tubes of the sizes given, the following times are ample. For 100 ml. 18 hrs; for 10 ml. 3 hrs; for 1 ml, 1 hr. The minimum times are certainly much shorter; though no exact measurements have been made, it is likely that 1 hr is sufficient for 10 ml. Naturally, large algae on the whole sink faster than small ones and where such are the only ones to be counted even shorter periods may be sufficient.

If the number of algae in the original sample is known or found to be too small for counting after direct sedimentation into the counting tubes used with the inverted microscope, it will be necessary to carry out their concentration in two steps. A suitable volume is run into some larger container such as the Nessler tube used in the colourimetric determination of ammonia or other substances. It may be necessary to determine by trial and error how large this volume should be, but this should not be so as, in almost all cases, the original test in the counting tubes will show how much the volume must be increased to obtain a large enough count. The algae are left to settle in this container, then the supernatant water is removed with a siphon and the sample washed into the counting tube in the manner described

below. Siphoning should be slow, the short arm of the siphon remaining just below the surface of the liquid. It is sometimes said that the siphon should have an upturned end to prevent algae being sucked up when the open end approaches the bottom of the sedimentation vessel. Tests have shown that this will not happen if reasonable precautions are taken, such as siphoning slowly and keeping the siphon steady. For example, using a 100 ml Nessler tube, the level may be reduced safely to 2 cm above the base, and with very slow siphoning (e.g. circa one drop per second) to 1 cm. This very slow siphoning need not be started until the level of the liquid is within 2 or 3 cm of the base. It may be impossible to reach so close to the base of the tube with a siphon with an upturned end without touching the bottom, when there is a real danger of disturbing the sediment. After reduction of the volume, the residue is stirred by shaking or rotating between the palms of the hands and poured into the appropriate sedimentation tube. Any algae remaining are removed by one or two rinsings with distilled water.

Sedimentation tubes are conveniently cleaned by rinsing with a jet of water followed by a detergent solution. The latter must not be used first, since it may form a precipitate with the iodine which is difficult to remove. No tube should be allowed to become dry after use, because some algae are then so firmly attached to the bottom that they are not removed by detergents. New tubes not treated with cleaning mixture (i.e. with polystyrene seal) can be cleaned in a solution of tribasic potassium phosphate.

#### 4. *Counting*

Before counting, a portion of the edges and central areas of the base of the tube should be examined with the appropriate objective to ensure that definition is good throughout, for the meniscus of the liquid in the tube may throw shadows or cause glare. In either case the removal or addition of liquid will cure this. It is essential to count discrete organisms though their constituent cells may be counted also at the same time (see p. 161).

By means of the mechanical stage, the whole of the bottom of the sedimentation tube can be examined in a regular manner (fig. 1b). As the stage is moved, the organisms lying between the two parallel cross hairs are counted as they appear to pass the vertical line. The only exceptions are the first and last traverses when the edge of the tube covers part of the field so that only one of the parallel lines is superimposed on this field.

It is best to cover the whole floor of the tube, since the distribution of the algae thereon is not always at random. However, if any orga-

nisms or particles are present in large numbers, the presence of an obviously non-random distribution will be evident. If this is absent, a convenient number of fields or transects may be covered, provided it is realised that exact confidence limits cannot be given for any count. It is quite impossible to judge by eye whether a distribution is or is not truly random.

Some of the organisms will lie across the horizontal hairs. Those across the upper one are counted as lying within the hairs but those across the lower are not because, when the next lower area of the base of the counting chamber is traversed, they will overlap the upper hair.

It is generally desired to distinguish between live and dead cells but this is, of course, in fact not wholly possible since a cell which has died recently will probably show no visible change in appearance. Each person therefore has to decide his own criteria for such borderline cases. Since there are likely to be differences of opinion about this, there is an inherent error in the method when counts by different workers are compared but, as will be seen (p. 166), this is so small compared to the natural variation in numbers in randomly distributed populations that it can be ignored. Since the present technique utilises only low power objectives, it is clearly not suitable for all the nanoplankton organisms though some, despite their size, are easily seen (notably those with starch as a reserve product). Quite apart from this defect, however, the various counting chambers devised for nanoplankton are to be preferred.

### III. A NOTE ON THE USE OF HAEMOCYTOMETERS

In the course of this investigation a comparison was made with counts using a haemocytometer in the standard manner for blood cell or bacterial counts. Replicate series of counts were always found to show statistically significant deviations, probably owing to the large size of some of the organisms, haemocytometers being devised for small cells. It was found, however, that this difficulty could be overcome (see p. 169) by the following procedure though this is clearly less satisfactory than using the UTERMÖHL technique. A suspension of the algae is made of sufficient richness in organisms to ensure that a reasonably large count (e.g. 50—100 organisms) can be made when the haemocytometer is filled. This suspension must be of sufficient volume to fill a vessel (e.g. a beaker) large enough to permit the haemocytometer cell to be held vertically by hand within the vessel. The special glass cover to the haemocytometer is held against the haemocytometer cell and above its counting chamber with the thumb. The suspension is now dispersed by agitating the water with the

haemocytometer which is kept approximately vertical and then the coverglass is rapidly slid over the counting chamber by a movement of the thumb. The haemocytometer is at once removed from the vessel and placed on a flat surface, the external moisture is removed with absorbent paper and a count made in the normal manner.

#### IV. THE COLLECTION OF WATER SAMPLES WITH A RUBBER HOSEPIPE

In the present investigation, samples of phytoplankton or of cultures of plankton algae were used, but the method is applicable to samples from any source provided random distribution occurs or can be produced by, for example, shaking. The plankton samples were collected either by the use of rubber hose or with a Friedinger water bottle.

The principle of the former method (described in LUND 1949) is that a weighted flexible tube, made of rubber or polyvinyl chloride (P.V.C.), is lowered slowly into the water so as to collect a uniform sample of the whole of a water column to a depth equal to the length of this tube. With other samplers it is necessary to take a series of samples at more or less short distances apart in order to determine the size of a population in a column of water. The choice of the depth intervals is largely arbitrary and so one may as easily obtain a wrong estimate as a right one. The use of rubber hosepipe has other advantages. It is virtually unbreakable, portable, long-lasting, cheap, easily made and can be used from the smallest boat. With samples of different length and bore, the method is suitable for lakes, weed beds or ponds. Sampling is speedy; with a hosepipe of 2.5 cm internal diameter a 5 m column of water can be collected in under two minutes. Consequently a series of samples can be taken in a short time if it is wished to determine the horizontal distribution of a population. With narrow tubes, samples can be collected from weed beds without disturbing these plants, as other samplers may do, thereby getting a false picture of the distribution of the free-living algae. The chief limitation of the method lies in the depth to which sampling can go; a convenient length of tube is 5 m, more than 10 m is inconvenient unless a large boat is available. The samples collected can also be used for chemical analysis except possibly for the determination of alkalinity, and so of calcium also, and probably of zinc. The rubber will contain either calcium carbonate or zinc, or both. Calcium carbonate may be used as a filler but, as this is not generally the case, a tube not containing it can be bought. Zinc is more generally used in the manufacture of rubber hose and, to avoid this, it will be necessary to utilise a plastic

tube. If other trace elements such as lead are to be estimated the tube should be weighted with a suitable coated or metal-free substance.

## V. STATISTICAL PROCEDURE

In the next part of the paper simple methods are described for finding the precision of single counts and testing for randomness. A table is given showing the size of count necessary to attain various degrees of accuracy if randomness has been established.

In section VI are described the experiments which tested the validity of the method used in determining the precision of counts. In general the aim has been to determine the main sources of error and their magnitude. The main types of error discussed include sampling errors and counting errors, and also errors arising by counting colonies and then multiplying by a mean number of cells per colony to derive an estimate of cell numbers.

Finally counts made by the alternative method described by LUND (1951) and by haemocytometer are analysed briefly.

### 1. *Estimating precision of counts*

All methods of estimating the abundance of algae which involve taking samples from a large population such as that in a lake or culture flask will be subject to the chance errors involved in any sampling process. These errors are often only apparent in the counting method but similar errors of a similar size must be present in all methods. The weighing and chlorophyll methods may normally deal with larger samples of algae and therefore be subject to somewhat smaller relative errors, but it is quite possible that they may involve other complicating errors due to the denser populations sampled.

The accuracy of result required for estimating algal populations is not, in any case, normally very large. Most experimental and ecological observations are concerned with generations, or changes in abundance of 100 %. In such investigations then a method which can estimate abundance to an accuracy of  $\pm 50$  % is quite adequate and any time spent in making more accurate estimates is largely wasted. The accuracy to which an investigator works must be decided by him on common-sense grounds but the statisticians' conventional "significant" level (a chance of one in twenty of being wrong) is a good working one, and an accuracy greater than the "highly significant" level (a chance of only one in a hundred of being wrong) is

rarely required. As will be shown in a later section, if an algologist decides to adopt the 'highly significant' level he will normally be quite safe in counting no more than 100 algae on each occasion as a count of that number will tell him with a probability of 99/100 that the real population abundance for the same volume of water lies between 77 and 130, which is considerably better than the  $\pm 50\%$  which he will normally require.

It is obviously important to be able to calculate the accuracy of counts made by the methods previously described, especially for the purpose of comparing different counts. If the complete organisms are randomly distributed (the questions of testing for randomness and of counting colonial forms will be discussed later) then the precision of a single count can be read off from published tables (RICKER 1937 or PEARSON & HARTLEY 1954) or from figure 2. For each number counted the upper and lower limits are shown within which the true value may be expected, with a preselected chance (confidence coefficient) of the statement being correct. Thus a 0.95 confidence coefficient denotes a probability of being right ninety-five times in a hundred or nineteen times in twenty, and conversely of being wrong (i.e. the true value being outside the limits) five times in a hundred or once in twenty. For example, if a count has been made yielding 20 organisms, we can state by reference to the tables or figure 2 (with a chance of one in twenty of being wrong) that the true value lies between 12 and 31. This information can be used for comparing different counts. If one count lies within the confidence limits of another there is no significant difference between them. If the confidence limits of two counts do not overlap there is a significant difference between the counts (e.g. a count of 25 does not differ significantly from a count of 30, it does differ significantly from a count of 7). The confidence limits of counts up to 50 are shown in *Biometrika Tables for Statisticians Vol. 1. 1954, Table 40, page 203*, for five confidence coefficients. RICKER also gives confidence limits of counts up to 50 for confidence coefficients 0.99 and 0.95 and gives the following formulae for extrapolation:

Confidence coefficient 0.99

$$\begin{aligned} \text{Upper limit} &= x + 3.82 + 2.576 \sqrt{(x + 2.2)} \\ \text{Lower limit} &= x + 2.82 - 2.576 \sqrt{(x + 1.2)} \end{aligned}$$

Confidence coefficient 0.95

$$\begin{aligned} \text{Upper limit} &= x + 2.42 + 1.960 \sqrt{(x + 1.5)} \\ \text{Lower limit} &= x + 1.42 - 1.960 \sqrt{(x + 0.5)} \end{aligned}$$

where  $x$  is the count of a single sample.

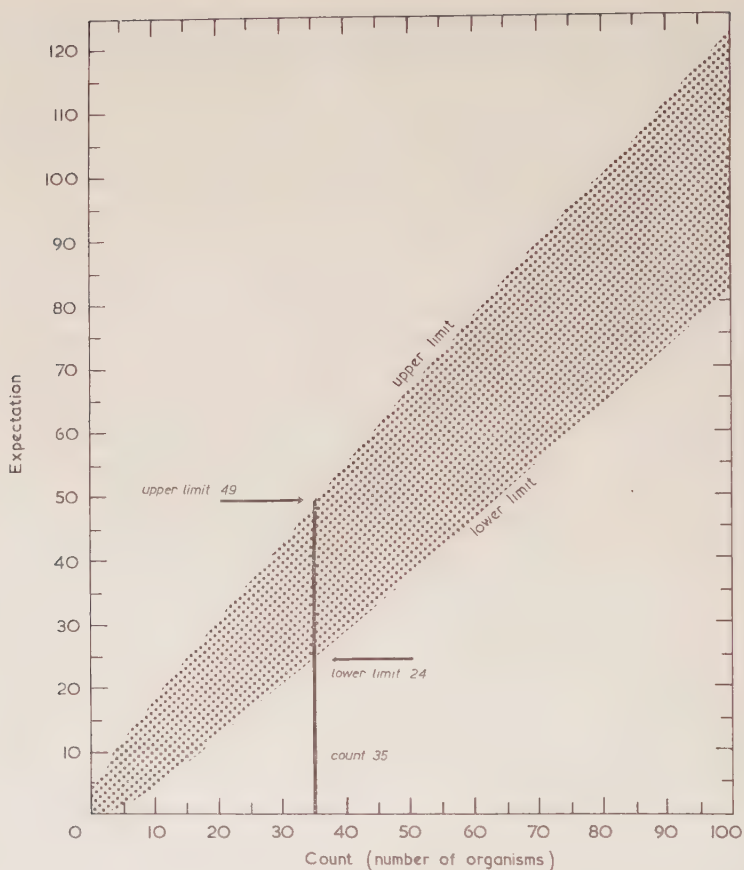


Figure 2. The 0.95 confidence limits for the expectation of a Poisson variable.

For the confidence limits of a single count find the count on the horizontal axis and draw a vertical line through it. The limits are read off from the vertical axis at the points where this line cuts the upper and lower boundaries of the shaded zone. These limits will include the true expectation at least 95 times out of a 100.

Example: For a count of 35 the limits are:—

Lower 24

Upper 49

Figure 2 shows the upper and lower limits for confidence coefficient 0.95 for counts up to 100. For comparing counts PEARSON & HARTLEY (1954) in Table 36 provide a simple and rapid method of testing the significance of the difference between two randomly distributed counts whose sum is 80 or less. For most practical purposes the following simplified criteria have been found to be adequate. The difference between the counts is significant if the confidence limits do not overlap. It is not significant if one actual count lies wit-

hin the confidence limits of the other. There will of course be intermediate cases, and exact statistical tests are available and may be found in any standard text book, but for the accuracy usually required in algal work the above simple procedure is probably sufficient in most cases.

For some colonial forms the confidence limits in terms of cell numbers can be calculated by finding the confidence limits for the count of complete organisms, and then multiplying these by the mean number of cells per colony in these same organisms. This method can only be applied when the number of cells per colony does not vary widely and the cells in each colony can be counted without breaking up the organism. It cannot be used, however, for very large colonies which have to be boiled up to separate the cells, or where the number of cells per colony can vary widely (e.g. many Myxophyceae etc. with a possible range of 10—10,000 cells per colony). The mean number of cells per colony can only be estimated in this case, introducing a further source of error, and to assume normal distribution would be completely unreal. For such organisms the confidence limits would be very wide, and accurate determination would require many counts to establish the cells per colony distribution and hence a combined error (p. 167. At present there is no satisfactory simple method of determining the accuracy of cell counts of very large colonies. GILBERT (1942) when investigating the errors of the Sedgewick-Rafter counting chamber in the enumeration of marine phytoplankton, similarly found that the distribution of colonies and non-colonial cells closely approximated to the Poisson distribution but that the frequency distribution of counts of total cells was unpredictable. He used an empirical method to estimate the error of total cells. HOLMES & WIDRIG (1956), apparently counting total cells (not colonies), used the Negative Binomial to derive confidence limits for counts of marine phytoplankton. Some of the resulting limits appear to be very wide.

TABLE 1.  
Confidence limits for the expectation of a Poisson variable

Confidence Coefficient	0.95 once in 20		0.99 once in 100		0.998 once in 500		0.999999 once in 1,000,000	
Count	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
10	5	18	4	21	3	24	—	28
50	37	66	34	71	31	76	20	88
100	82	122	77	129	72	135	56	152

When confidence limits can be calculated it may be objected that statements that one in so many counts may be expected to be outside such limits are too vague, without giving some indication of how far out aberrant counts are likely to be. The answer is that they are not likely to be very far out. Table 1 shows various probabilities for counts of 10, 50 and 100. We can see from the table that only once in a million samples when the expected count is 100 would the observed count lie outside the range 56—152 by chance, (a safe enough bet if 50 % accuracy is required).

## 2. Size of counts

If the distribution of the organisms has been shown to be random it is possible to calculate the number of organisms to be counted to achieve any desired level of accuracy. Table 2 using 0.95 confidence coefficient shows approximate numbers which must be counted to obtain various accuracies (expressed as percentage of count). For example to achieve 10 % accuracy a count of 400 is needed. The confidence limits corresponding to this count would be approximately 400 minus 10 % of 400 and 400 plus 10 % of 400, that is from 360 to 440. Table 2 is only intended to give a rough idea of the size of count needed for various accuracies, and in practice should not be used to calculate confidence limits. It should be noted that the accuracy depends entirely on the total size of the count. This total may have comprised a few large samples or many small samples without altering the accuracy achieved.

As the accuracy of a count varies indirectly as the square root of the number counted, to obtain any degree of increase of accuracy it is necessary to make very much larger counts. Thus (see table 2) to obtain twice the accuracy four times the number of organisms must be

TABLE 2.  
Size of count and accuracy obtained.

Approximate 0.95 confidence limits		
Number of organisms counted	Expressed as percentage of count	Range
4	± 100%	0—8
16	± 50%	8—24
100	± 20%	80—120
400	± 10%	360—440
1,600	± 5%	1,520—1,680
10,000	± 2%	9,800—10,200
40,000	± 1%	39,600—40,400

counted. For example a count of 100 has an accuracy of 20 %, and a count of 400 an accuracy of 10 %, for the same confidence coefficient. It is thus rarely worth while counting more than the minimum number necessary to provide the required degree of accuracy.

### 3. $\chi^2$ test for randomness

The  $\chi^2$  test (FISHER 1944) provides a quick and simple method of testing for randomness. An imaginary example will be given to show the method of calculation. It will be assumed that a set of five (n) replicate counts has been made giving 20, 40, 30, 25, 25 (x) organisms. Are these randomly distributed? The sum ( $\Sigma x$ ) of these counts is 140, and of their squares ( $\Sigma x^2$ ) 4150. The mean count ( $\bar{x}$ ) is  $140/5 = 28$ .

Now

$$\chi^2 = \frac{\Sigma(x - \bar{x})^2}{\bar{x}}$$

$\Sigma(x - \bar{x})^2$  can be calculated directly thus:

$(x - \bar{x})$	$(x - \bar{x})$	$(x - \bar{x})^2$
20 — 28	— 8	64
40 — 28	+ 12	144
30 — 28	+ 2	4
25 — 28	— 3	9
25 — 28	— 3	9
		<hr/>
		$\Sigma (x - \bar{x})^2 = 230$

or more quickly by using the formula

$$\begin{aligned}\Sigma (x - \bar{x})^2 &= \Sigma x^2 - \bar{x} \Sigma x \\ &= 4150 - 3920 \\ &= 230 \text{ as before}\end{aligned}$$

Hence  $\chi^2 = 230/28 = 8.21$ .

Reference to tables of  $\chi^2$  or figure 3 shows that for  $n-1 = 5-1 = 4$  degrees of freedom a  $\chi^2$  of 8.21 is not significant at the 0.95 probability level. The hypothesis of random distribution according to the Poisson law is therefore not disproved.

To determine whether a system is randomly distributed a series of such tests should be done. If possible at least 10 sets each containing not less than 5 replicate counts should be tested for randomness. It depends entirely on individual circumstances how the sets are composed. For example it may be desired to test whether an organism is randomly distributed vertically. In this case a set of counts would be

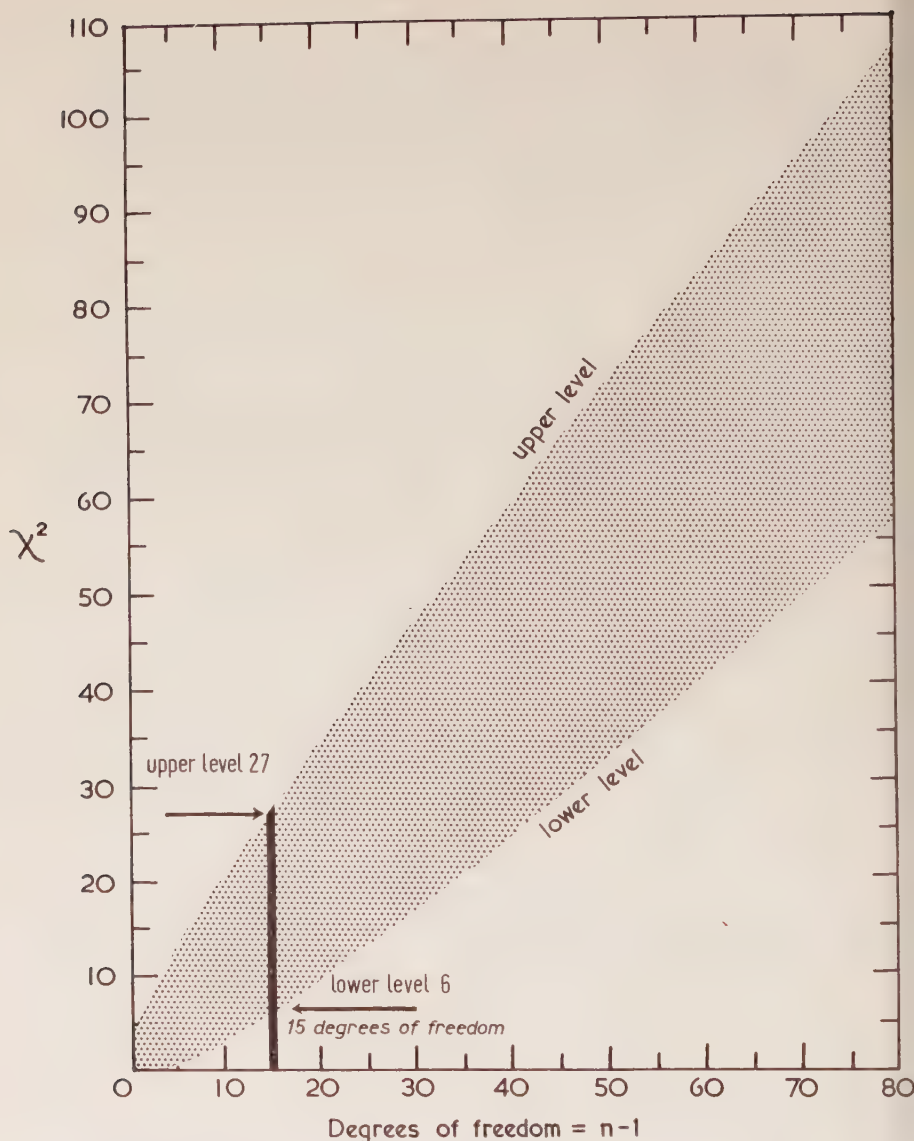


Figure 3. The 0.95 probability levels of  $\chi^2$ .

To find whether any particular value of  $\chi^2$  is significant find the number of degrees of freedom (which, for the test described, equals the number of counts minus one) on the horizontal axis. Draw a vertical line through this. If a horizontal line drawn through the  $\chi^2$  value cuts this vertical line inside the shaded zone then the  $\chi^2$  is *not significant*. If the lines cut outside the shaded zone then  $\chi^2$  is *significant* at the 0.95 probability level.

Example: for 15 degrees of freedom any value of  $\chi^2$  between 6 and 27 is *not significant*.

(Note: Much greater accuracy may be obtained by using tables of  $\chi^2$  tabulated to several places of decimals).

made from samples taken from several depths, one count from each depth, the whole procedure of sampling and counting being repeated on several occasions. If results are not significant, then it can be assumed that the organisms are distributed randomly, and subsequently a single count can be used for determining confidence limits and accuracy by the methods previously described.

A series of such tests should be done whenever it is suspected that the distribution of the algae may have altered, for instance during thermal stratification, or with a considerable change of population density.

## VI. ANALYSIS OF ERRORS

To find the errors involved and hence the confidence limits (see p. 154), it is necessary to know how the organism is distributed in space. The distribution can be uniform, random or clumped. If a satisfactory theoretical model can be found to fit observed results this can be used to estimate the errors of future counts.

In theory if a plankton organism is randomly distributed in a lake or culture flask, and samples small relative to the total population are removed and counted by an effective process, the counts should be distributed according to the Poisson series, and the variation between replicate samples be due to random sampling errors. Further, if randomness (i.e. agreement with the Poisson series) is established, it is possible to calculate standard errors and confidence limits for a count of a single sample (RICKER 1937, FISHER 1944) by the methods previously described. This is of obvious practical value.

The use of the Poisson distribution involves three conditions. Firstly, the items counted must be separate discrete units. This is fulfilled for most algae if the statistical treatment is carried out on counts of colonies, filaments etc. instead of their component cells. Such counts and confidence limits derived from them can subsequently be multiplied up to obtain the required population densities in terms of cell numbers. This has been done for *Asterionella* in the present work. Secondly, the sample should be small relative to the population. Where a sample of a litre or so of water is removed from a lake this condition is obviously fulfilled. When the population density is low, however, relatively large sub-samples may be pipetted out of the water sample. From the results obtained in these few instances it would appear that this does not invalidate the use of the Poisson distribution. Thirdly, the plankton organisms must be randomly distributed in the body of water being sampled. If the organisms tend to clump together greater variation between replicates will be

found than would be expected according to the random theoretical model and  $\chi^2$  (see p. 159) will be significantly large. If the organisms tend to be equally spaced, the variation will be less than expected and  $\chi^2$  will be significantly small.

The description in section V (1) of how to estimate the accuracy of a count is based on the assumption that the only important error is the random error. This assumption was tested as follows by considering the three main groups of errors. First there are random errors due to sampling and sub-sampling, secondly errors in the actual counting process, and thirdly, when colonial forms are counted, errors in estimating the mean number of cells per colony and hence converting colony counts into estimates of cell population density. These three types of error have been separately investigated by replication of successive stages of the method and statistical analysis of the variation.

No exhaustive analysis of all the possible sources of error has been attempted, though in general the analysis has been rather more detailed than would be necessary for the accuracy required in ordinary routine sampling and counting.

Some of the data on variation among replicate counts have been obtained from experiments designed to provide this information, but much has been derived from samples originally obtained for other purposes.

### 1. *Lake sampling*

The errors involved in lake sampling have been analysed by applying the  $\chi^2$  test for randomness to various series of samples. The data for *Asterionella* are tabulated in Table 3a. In each case the set of samples were collected at the same time by rubber hose or water bottle and one sub-sample from each sample sedimented and counted. The population density and number of colonies counted varied widely through the set of series. In some cases the sub-sampling involved dilution, in others concentration, before the final sedimentation.

Series 1—24 were not strict replicates, but were water bottle samples made at the same station on different days at depths 0, 1, 2, 3, 4 and 5 m (some series being incomplete owing to one or more depths having been missed out). Throughout this set the lake was isothermal and therefore well mixed. A sample was taken by rubber hose at the same place and time as each of the series 1—24, and in every case the count from this was within the limits of variation found from the water bottle samples. Series 25—30 were a similar set

Table 3a *Asterionella*      Replicate lake samples  
 3b Desmids *Uroglena*      "      "      "

3a	<i>Asterionella</i> Series	Depth	Mean colony count	Number of samples	$\chi^2$
	1	0—5m	38	6	7.0
	2	"	34	4	4.5
	3	"	25	6	11.8
	4	"	27	5	9.4
	5	"	28	6	1.5
	6	"	36	5	3.9
	7	"	50	6	8.7
	8	"	82	6	2.3
	9	"	121	6	4.3
	10	"	100	5	5.4
	11	"	251	6	8.8
	12	"	86	6	3.2
	13	"	101	6	5.0
	14	"	73	6	3.8
	15	"	85	6	3.7
	16	"	160	6	2.4
	17	"	302	5	4.7
	18	"	329	5	6.8
	19	"	263	4	1.9
	20	"	4	3	2.0
	21	"	56	2	0.3
	22	"	121	2	0.3
	23	"	63	3	0.7
	24	"	53	3	0.1
	25	0—60m	31	15	12.5
	26	"	28	19	22.6
	27	"	29	19	26.4
	28	"	27	18	22.4
	29	"	30	19	20.3
	30	"	38	19	17.6
	31	0—5m	14	10	10.4
	32	"	16	10	28.1**
	33	"	63	10	5.7
	34	"	88	9	6.7
	35	"	279	24	33.0
	36	"	176	3	0.3
1—36 Total					308.6
3b	Desmids	5m	36	10	8.8
	<i>Uroglena</i>		26	4	62.0**

\*\* denotes very significant difference (0.99 probability level) from random distribution.

of water bottle samples, though here the samples were collected at regular depths down to 60 m or nearly the bottom of the lake. This set extended over a longer period than those shown in this table, which covers isothermal conditions only. Series 31—35 were rubber hose samples made to test the variation at different population densities between replicate lake samples. The different sets were from different lakes in order to cover a range of population densities. Series 36 was a single series made for comparison of *Asterionella* with *Uroglena* (see Table 3b). It can be seen from Table 3a that though the mean colony count ranged from 4 to 329 only one of the thirty-six *Asterionella* series had a distribution differing significantly from random expectation. Replicate lake samples of Desmids and *Uroglena* were also tested for randomness, the results are given in Table 3b. Desmids from ten hauls each at 5 m depth were counted and found to be randomly distributed. Counts of *Uroglena* from four replicate lake samples gave a very significant difference from expectation, although a parallel count showed *Asterionella* (Series 36) to be randomly distributed at the same place and time. It seems therefore

TABLE 4.  
Vertical Distribution of *Asterionella*

Date 1947	Mean number of cells per 100 ml.	Number of samples	$\chi^2$
13th Jan	31	15	12.5
20th Jan	28	19	22.6
27th Jan	29	19	26.4
3rd Feb	27	18	22.4
10th Feb	30	19	20.3
18th Feb	38	19	17.6
24th Feb	46	20	50.1**
7th Mar	68	18	54.4**
14th Mar	86	12	12.8
20th Mar	89	16	81.9**
26th Mar	119	20	11.1
1st Apr	92	13	23.9*
9th Apr	248	19	27.2
15th Apr.	385	19	48.3**
22nd Apr	1112	20	109.3**
28th Apr	1527	20	28.6
5th May	2695	20	18.2

\*\* denotes very significant (0.99 probability level),

\* denotes significant (0.95 probability level) difference from random distribution.

The mean numbers from 13th Jan. to 18th Feb. do not differ significantly from each other.

that *Uroglena* can swim strongly enough under some conditions to overcome the randomizing effect of turbulence.

The results of the  $\chi^2$  test for randomness on counts of *Asterionella* in samples from 0—60 m taken between January and May 1947 are shown in Table 4. It includes Series 25—30 of Table 3a. The lake was isothermal up to 18th Feb. During this period distribution of *Asterionella* was random and numbers were stable. Between 18th—24th Feb. the lake was completely covered with ice. It will be noticed that as soon as the lake was stratified from ice-cover the distribution differed very significantly from Poisson. The distribution was random on 14th March (when the lake was again ice-free and there had been a strong east wind on the previous day), but it differed very significantly again on the 20th, (between these dates more snow had fallen and then general thaw had set in). During April, when the numbers were rising rapidly, very significant differences from expectation were found; in particular there were aberrant high counts in the samples from the lowest depths. The distribution was again random for the last two sets of counts, the series being terminated at the onset of summer stratification.

From these results it would appear that only in certain circumstances the most important condition of random distribution is fulfilled, the use of the Poisson distribution to calculate confidence limits being then justified.

## 2. Sub-sampling and Pipetting

The errors due to sub-sampling and pipetting were investigated by several series of replicate sub-samples. The results are shown in Table 5. First twenty replicate 1 ml sub-samples were pipetted from a sample of plankton, and the number of *Asterionella* colonies counted. This procedure was then repeated at a higher population density. A third series of counts was designed to find the errors arising from pipetting to dilute the sample. Twenty 1 ml samples were pipetted out and each was diluted to 100 ml. From each of these 100 ml samples a sample of 1 ml was pipetted out and counted. In all three series the errors were well within the range expected from random sampling. Further counts were carried out of various other species in replicate sub-samples. In some cases a parallel count of *Asterionella* was made from the same sub-sample. The organisms were found to be randomly distributed with the exception of *Ankistrodesmus* in one set of counts, which may of course have been due to chance.

TABLE 5.  
Replicate sub-samples

	Mean count	Number of sub- samples	$\chi^2$
<i>Asterionella</i>	76	20	16.3
„	162	20	22.7
„	164	20	24.4
<i>Melosira</i>	91	10	9.8
<i>Cyclotella</i>	67	10	12.6
<i>Asterionella</i>	252	10	10.3
<i>Synedra</i>	208	10	7.0
<i>Asterionella</i>	156	10	8.6
<i>Oscillatoria</i>	35	21	19.8
<i>Asterionella</i>	88	21	25.2
<i>Ankistrodesmus</i>	115	6	15.7*
„	93	4	6.5
<i>Tabellaria</i>	59	2	3.4

\* denotes significant (0.95 probability level) difference from random distribution.

### 3. Counting

The errors resulting from the actual enumeration of the colonies are of a different type from those due to sampling. The number arrived at depends on a series of individual decisions as to which colonies are alive or dead, and which are inside or beyond the line of demarcation of the area to be counted. A test was made to find the variations between two observers counting the same tube and also the variations for each observer counting the same tube on separate occasions. One tube was counted once each by two competent observers on ten successive days. The daily totals were only summed from the numbers recorded after the last count had been made, so that the later enumerations would not be influenced by previous results. The results were analysed statistically.

It was found that the counts of the two observers differed very significantly, the mean counts of each being 79 and 76 organisms, but that the counts of each observer were consistent. However, although the difference between the counts was very significant, it was very much less than the random error inherent in the method. Consideration of the random error had been eliminated from this experiment by using the same tube throughout.

#### 4. Colonial forms

Although biological interest is centred on counts of cells and their variation the study of distributions and tests for randomness must be carried out on complete organisms. In the case of *Asterionella* and many other planktonic algae the complete organism is the colony, not the cell. A series of 1000 counts of cells per colony in *Asterionella* was therefore made.

The number of cells per colony is a discontinuous distribution, and varies with time and place. Some examples of such distributions are shown in Figure 4. They tend in this case to be at least bimodal, with modes usually at 4 and 8 cells per colony.

To assess the importance of the sampling error of the cells per colony count an estimate was needed of the standard error of the mean of this count. When 51 samples of 10 colonies from the parent population of 1000 colonies were taken, the standard error of the mean was found to be 0.56. This compares reasonably with an independent estimate of 0.53 derived from the standard deviation of the parent distribution. For the calculation of combined errors estimates of the standard error of the mean were made in the same way using the assumption of normal distribution. The problem of estimating cell numbers for very large colonies has been discussed on p. 157.

#### 5. Estimating combined errors

To give some indication of the relative importance of the different types of error some examples of combined errors have been calculated. First combined random and personal counting errors are shown, and secondly combined random and cells per colony errors.

The experiment on replicate counts of the same tube showed that the personal counting error was very small. The personal counting error and the random error are independent, and the variances are additive. For the counts of 76 and 79 the inclusion of the personal counting error increases the standard error by only 0.2. Such increases are negligible. Further, if a series of counts on replicate samples shows a variation no more than that to be expected from a series of random samples, the counting can have added no significant error to the random error. Such has been the case with the test replicate series on *Asterionella*. It seems therefore that under these conditions the personal counting error can be ignored.

Some examples have been worked out of the effect of combining the error in counts of cells per colony with the random error. The two variables are independent, and their product gives the number

of cells. Using the formula for the variance of a product (YATES 1949) we calculated the combined errors for counts of 50 and 100 colonies with 7 as mean number of cells per colony. In the first example the combined standard error was 50.9 cells, an increase of 1.4. In the second the inclusion of the cells per colony error increased the standard error by 4.0 to 74 cells. It is clear that increases of this order are unimportant, and that the random error accounts for almost all the total variability.

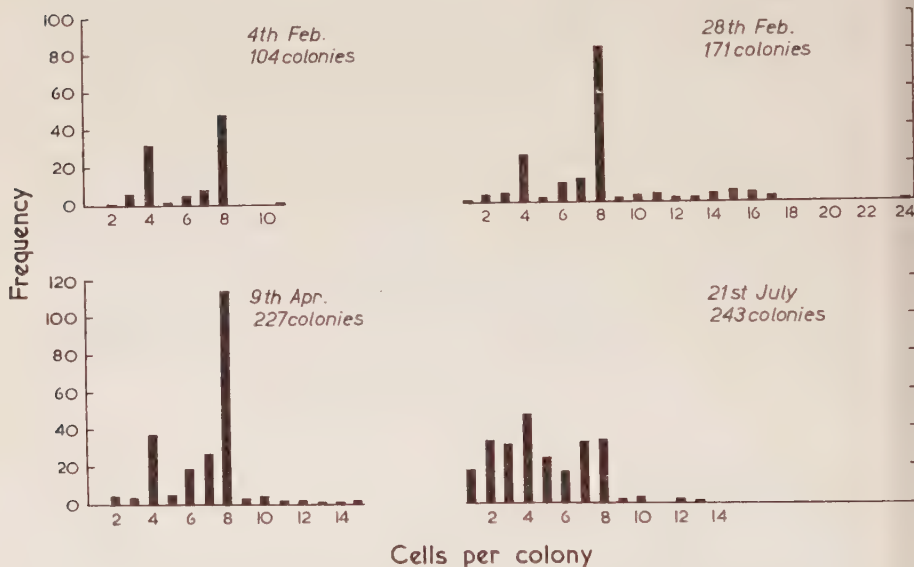


Figure 4. Frequency distributions of cells per colony.

It has been shown that the random sampling error comprises by far the largest part of the total standard error. Both the personal counting error and the cells per colony error have been found to be relatively unimportant. For practical purposes therefore confidence limits derived directly from counts of complete organisms (assuming or having shown these to be randomly distributed) give a reasonable measure of the precision of the estimate, and can be used for comparison between samples. For colonial forms a single count of colonies and of the cells (or filaments etc.) in these colonies is adequate to give confidence limits in terms of cell numbers, except for very large colonies.

## VII. ALTERNATIVE COUNTING TECHNIQUES

Counts made using the alternative method described by LUND (1951) were analysed statistically. Ten counts each of *Melosira*, *Cyclotella* and *Synedra* were found to be randomly distributed. Comparison was then made between the new technique and the inverted microscope method. Ten counts by each method gave mean counts which were very similar, 156.2 (new technique) and 156.5 (inverted microscope) for *Asterionella*; 197.2 and 208.3 for *Synedra*. In neither case was there a significant difference between the counts by the two methods.

### *Haemocytometer*

Counting tests were also carried out using a haemocytometer in the manner described on p. 152. Results from three sets of counts of *Asterionella* using this method showed that the cells were randomly distributed.

## SUMMARY

Various methods for the estimation of populations of algae and other small freshwater organisms are described. A method of counting is described in detail. It is basically that of UTERMÖHL and uses an inverted microscope.

If the organisms are randomly distributed, a single count is sufficient to obtain an estimate of their abundance and confidence limits for this estimate, even if pipetting, dilution or concentration are involved.

The errors in the actual counting and in converting colony counts to cell numbers are considered and found to be small relative to the random sampling error.

Data are also given for a variant of UTERMÖHL's method using a normal microscope and for a method of using a haemocytometer for the larger plankton algae.

## ACKNOWLEDGEMENTS

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# Fixation of sulphur in the muds of Lake Victoria

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## INTRODUCTION

During the course of an investigation into the distribution of sulphur in the water, mud and vegetation of Lake Victoria (HESSE, 1957), it was concluded that the most important factor limiting the concentration of sulphur in the lake water was the extremely slow rate of decomposition of the bottom deposits.

Sulphur, although present in large (0.3—1.0 % dry weight of mud) quantities was not, as expected, in the reduced form of sulphide but almost entirely in organic forms even at depths of fifteen metres below the mud surface, and was thus unavailable. Furthermore, on removal from the lake bed the muds exhibited no signs of decomposition. It had been noted by BEAUCHAMP (Private comm.) that if the mud was boiled and then left standing overnight a disagreeable smell developed and bacterial growth increased. It was subsequently found by the author that removal of sulphates and other salts from the mud by washing with MORGAN'S reagent\* had the same effect upon its decomposition as had boiling, namely production of mercaptans and increased bacterial activity; drying followed by re-wetting the mud produced a similar effect.

Thus a series of experiments have been carried out with the object of determining the nature of the decomposition of the bottom deposits in Lake Victoria and of investigating the factors affecting such decomposition.

A subsidiary factor affecting the concentration of sulphur in the

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\* MORGAN'S reagent: Sodium acetate-Acetic acid mixture buffered to pH 4—5.

lake water is the fixation of sulphate as such by the mud. As reported in the previous publication, although the top 3 cm of mud in Pilkington Bay contained over 70 p.p.m.  $\text{SO}_4\text{-S}$  extractable by MORGAN's reagent, the lake water filtered from that mud contained less than 1 p.p.m.  $\text{SO}_4\text{-S}$ . It was at first thought that this phenomenon was due to adsorption of sulphate ions by ferric complexes in the oxidised surface layers. That this adsorption process can and does occur in oxidised muds has been well established by other workers notably MORTIMER (1941), who also demonstrated that if such muds were kept under anaerobic conditions the ferric complexes were destroyed by reduction and so liberated the adsorbed ions. Experiments similar to those of MORTIMER using Lake Victoria muds did not, however, give the expected results and the matter has been further investigated.

## EXPERIMENTS AND RESULTS

### Decomposition of muds.

The mud used was obtained from Pilkington Bay at the north end of Lake Victoria and was collected and analysed by the methods previously described.

Mud collected from 0—10 cm was kept in an apparatus similar to that described by ALLEN et alia (1953) which essentially measures the rate of evolution of gases from an anaerobically decomposing material. No readable volumes were obtained over a period of two months, whereas the Thames estuary mud used by the above workers gave approximately 50 cc of gas in ten days. This experiment then, merely confirmed the slow rate of decomposition of the Lake Victoria mud.

TABLE 1

The treatments of mud from Pilkington Bay subsequently stored aerobically and anaerobically

Sample	Treatment
1	No treatment, stored aerobically without added sulphate
2	No treatment, stored anaerobically without added sulphate
3	No treatment, stored aerobically with sulphate added to water
4	No treatment, stored anaerobically with added sulphate
5	Washed free of sulphate with Morgan's reagent the excess of which washed out with water and pH restored to 7. Stored aerobically with added sulphate.
6	Oven-dried, re-wetted and stored anaerobically with added sulphate
7	Boiled and stored aerobically with added sulphate
8	Boiled and stored anaerobically with added sulphate

Freshly collected mud was filtered from excess water and divided into eight equal aliquots. The muds were then treated in various ways as described in Table 1 after which they were placed in jars which were then completely filled with lake water to which sodium sulphate had been added to give a solution of approximately 100 p.p.m. S. Two exceptions, samples 1 and 2, were covered with lake water without added sulphate. All jars were then stored either aerobically or anaerobically as indicated in the table. The anaerobically kept jars were sealed and stored under water in the dark and the aerobically kept jars were left open to the air with occasional stirring.

The jar containing mud treated with MORGAN'S reagent began to smell of mercaptans within a few days and gradually the water became cloudy and black with a brown scum on the surface. The same smell together with that of hydrogen sulphide was apparent in the jar containing anaerobically kept oven-dried mud. Hydrogen sulphide was also present in the water of the jar of fresh mud with added sulphate anaerobically stored. The muds and waters were analysed for sulphate and sulphide and the main conclusions formed from the experiment were:

- a. Aerobically stored mud sorbs some sulphate from the overlying water.
- b. Anaerobically stored mud to which no extra sulphate has been added produces no sulphide.
- c. Anaerobically stored mud to which sulphate has been added does produce sulphide.
- d. Aerobically stored mud which has been treated with Morgan's reagent produces sulphide and mercaptans.
- e. Mud previously oven-dried and then stored anaerobically with added sulphate produces sulphide and mercaptans.
- f. Boiled mud stored anaerobically with added sulphate produces sulphide.
- g. Boiled mud stored aerobically with added sulphate produces sulphide and mercaptans.

Two important facts were thus obtained; firstly the experiment indicated that sulphate already present in the mud is not anaerobically reduced to sulphide whereas some of the sulphate added to the mud is so reduced. Secondly, boiling, drying or washing with MORGAN'S reagent profoundly affects the subsequent decomposition of the mud. The nature of these treatments has not yet been found but in any case the problem is surely complex involving both biological and chemical changes.

One further experiment on decomposition rates and factors affecting them was carried out using the respirometer technique recently

TABLE 2

Treatments given to muds kept in respirometer

All muds were freshly collected from Pilkington Bay and a blank was used consisting of sterile sand covered with boiled out distilled water. In every case mud was taken in weight equivalent to 30 g of filtered mud.

Depth from mud surface	Treatment
0— 20 cm	Filtered from excess water
0— 20 cm	Left completely waterlogged
20— 50 cm	Filtered from excess water
20— 50 cm	Left completely waterlogged
200—250 cm	Filtered from excess water
200—250 cm	Left completely waterlogged
0— 20 cm	Boiled and filtered from excess water
0— 20 cm	Boiled and left waterlogged
0— 20 cm	Oven-dried and re-wetted with lake water to 30%
0— 20 cm	Filtered from excess water and admixed with KNO <sub>2</sub>
0— 20 cm	Washed free of sulphate with Morgan's reagent and restored to pH 8 with sodium bicarbonate
0— 20 cm	Washed free of sulphate as above and waterlogged with lake water

TABLE 3

Sulphur changes during the decomposition of mud from Pilkington Bay

Sample	p.p.m. S in dry weight of mud			
	Initial		After one month	
	SO <sub>4</sub> -S	Sulphide-S	SO <sub>4</sub> -S	Sulphide-S
0— 20 cm filtered	264	0	703	0
0— 20 cm waterlogged	264	0	12	0
20— 50 cm filtered	278	0	1014	0
20— 50 cm waterlogged	278	0	150	0
200—250 cm filtered	368	0	1400	0
200—250 cm waterlogged	368	0	111	0
0— 20 cm boiled & filtered	347	0	92	0
0— 20 cm boiled & waterlogged	347	0	0	2340

described by BIRCH & FRIEND (1956). The apparatus measures the rate of oxygen uptake and carbon dioxide evolution and is sensitive to small changes in organic carbon. The accuracy of the measurements was increased by shortening the length of the side tubes and raising the level of the acid dishes; this minimised temperature effects as the side tubes are outside the thermostat. The mud was given various treatments as summarised in Table 2 and typical rates of oxidation are shown in figures 1 and 2. The muds were analysed before and

after the experiment and some of the sulphate-sulphide figures are given in Table 3.

The respirometer experiment showed the very slow rate at which the natural mud of Lake Victoria is decomposing. Filtering off the excess water slightly increased the rate of decomposition as did the addition of readily available nitrogen, and boiling, drying or washing

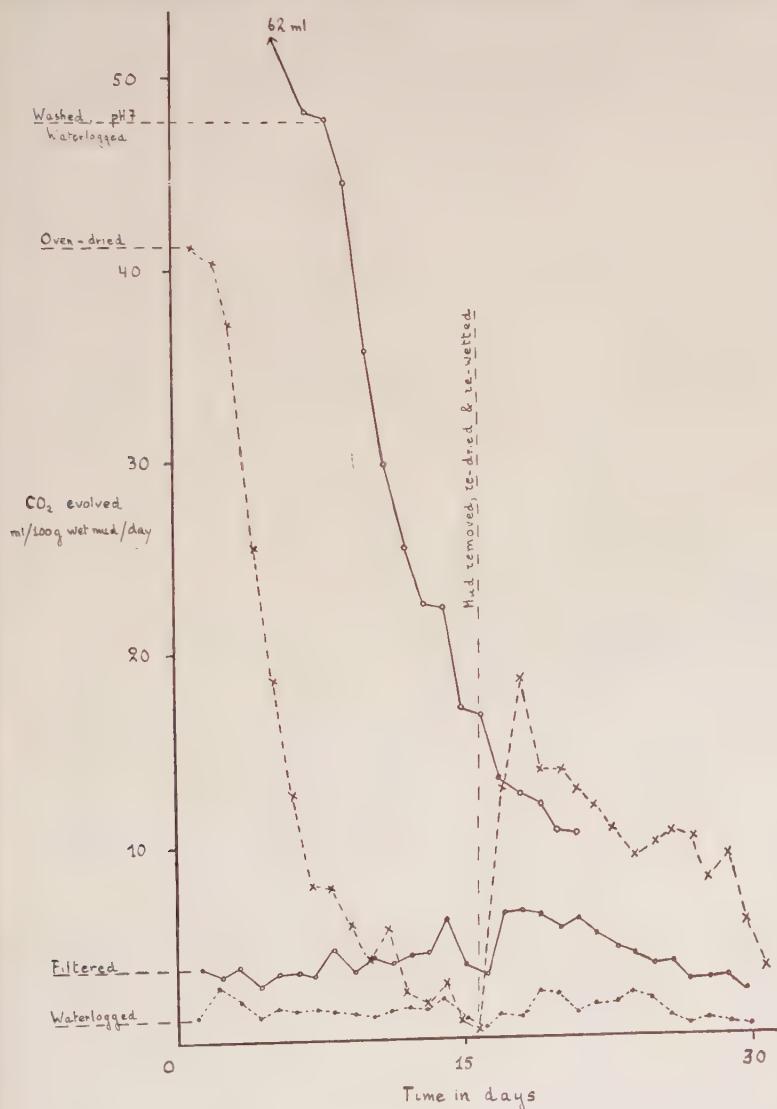


Fig. 1. The effect of various treatments upon the rate of decomposition of mud collected at 0—20 cm from Pilkington Bay.

the mud with MORGAN's reagent accelerated the progress of decomposition. Mud autoclaved at 17 lbs/sq. inch pressure for thirty minutes showed no signs of decomposition when the bottles were connected to the acid by means of sterile tubes plugged with sterile wool but similarly treated mud subsequently inoculated with fresh mud decomposed in the same manner as did boiled mud (Fig. 2).

The oven-dried mud decomposed very rapidly at first and then gradually its rate of oxidation decreased. On removing the mud from the apparatus and re-drying and re-wetting it, a higher rate of oxidation was restored (Fig. 1).

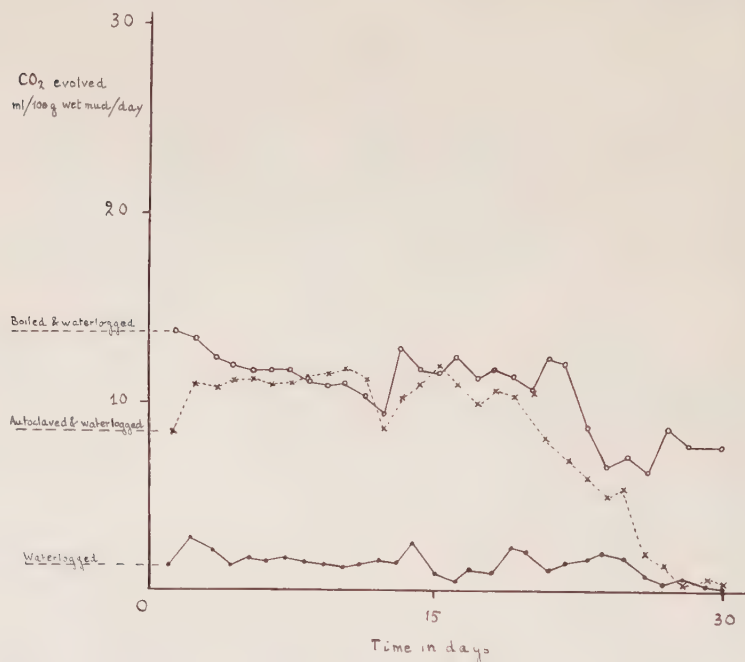


Fig. 2. The effect of boiling and autoclaving upon the rate of decomposition of waterlogged muds.

The main point arising from the experiment is the difference in behaviour of filtered and waterlogged fresh muds. In every case the filtered muds increased their sulphate content whereas the waterlogged muds lost sulphate. In no case did the sulphate in a fresh, waterlogged mud become reduced to sulphide although the sulphate of the boiled waterlogged mud was completely reduced. From the very high sulphide content of the boiled, waterlogged mud it appears that some of the organically bound sulphur was also converted. The gain in sulphate by the aerobically decomposing muds could be

explained by an oxidation of organic sulphur and in the absence of any microbiological data it is tentatively suggested that the loss of sulphate from the waterlogged muds is due to assimilation by micro-organisms. It is not considered that the loss of sulphur is due to a loss of hydrogen sulphide as a subsidiary experiment showed that iron and manganese in the mud immediately fix any free sulphides. On the assumption that sulphate assimilating organisms are active in the mud, boiling presumably destroys such organisms and permits decomposition to take place. Further experiments on factors affecting the decomposition of the mud are in progress.

### **Sorption of sulphates.**

Using the apparatus and techniques devised by MORTIMER, mud was subjected to various treatments and kept under aerobic and anaerobic conditions for a period of eight weeks. The results indicated that during the period of this experiment anaerobic conditions do not cause the liberation of sulphate ions from the mud although the overlying water was completely de-oxygenated and all the ferric iron was converted to ferrous. Furthermore, sulphate added to the mud kept in an oxidised state was not sorbed to any great extent. Whereas sulphate initially present in the mud was not reduced to sulphide under anaerobic conditions, that added to the water as sodium sulphate was almost entirely reduced, a finding in agreement with the experiments on decomposition of muds. This experiment then, indicated that the lack of exchange of sulphate between the mud and water of the lake is not solely due to sorption by ferric complexes.

If sulphates were being sorbed by ferric complexes then the treatment of the muds with a 'blocking' reagent such as 8-Hydroxyquinoline (oxine) or alizarin-S which would form insoluble compounds or stable chelates with the ferric ions, should prevent or reduce such sorption. Experiments performed in the study of phosphate sorption by soils showed that N/2 acetic acid containing 5% of oxine dissolved more phosphate out of phosphate-fixing soils than did acetic acid alone (GHANI, 1943). Consequently mud collected from 0—10 cm in Pilkington and Thruston bays was filtered from excess water, the filtrate being analysed for sulphate and aliquots extracted with MORGAN'S reagent, N/2 acetic acid and acetic acid containing 5% oxine. The results are given in Table 4 and show that oxine has no blocking effect upon the sorption of sulphate as just as much of the salt was extracted by acetic acid alone as in the presence of oxine. This then, confirms the results of the previous expe-

riment in that ferric complexes appear to be uninvolved in the fixation of sulphate, or at least have a minor effect. However, Table 4 also shows that whereas MORGAN's reagent and acetic acid removed over 70 p.p.m.  $\text{SO}_4\text{-S}$  from the Pilkington Bay mud, very much less was extracted from the Thruston Bay mud. Such figures are confirmed by those previously published when it was also pointed out that although the upper layers of mud in both bays contained much silica (10—20% of dry weight of mud), that from Pilkington Bay consisted mainly of diatom frustules whereas that from Thruston Bay was principally in the form of sand. If the seat of sulphate sorption was located in the diatomite in Pilkington Bay the observed facts would be explained. That is, we would expect the sandy mud of Thruston Bay to sorb little sulphate compared to that of Pilkington Bay and furthermore, neither anaerobic conditions nor treatment with oxine would affect such sorption.

TABLE 4

The effect of different solutions upon the extraction of sorbed sulphate

Extractant	$\text{SO}_4\text{-S}$ in extract corresponding to p.p.m. dry mud	
	Pilkington Bay mud, 0—10 cm	Thruston Bay mud, 0—10 cm
Distilled water	< 10	0
MORGAN's reagent	76	10
N/2 acetic acid	76	4
Acetic acid + 5% W oxine	75	0
p.p.m. $\text{SO}_4\text{-S}$ in lake water filtered from mud	0	0

In order to test this hypothesis mud from both bays and a sample of commercially pure diatomite were extracted three times with MORGAN's reagent the excess of which was washed out with distilled water. The samples were then shaken three times with a borate buffer solution at pH 9 to return the mud to its natural condition as when under lake water at that pH, and then once with buffer solution containing 100 p.p.m.  $\text{SO}_4\text{-S}$ . The final filtrate was analysed for sulphate. The results are given in Table 5 and show that both diatomite and Pilkington Bay mud sorbed approximately half the added sulphate whereas the mud from Thruston Bay sorbed very little sulphate. Investigation by BEAUCHAMP of the deeper layers of mud in Thruston Bay which contained far more sorbed sulphate has revealed an increased concentration of diatom frustules in the silica fraction.

It was concluded from these experiments that the presence of large amounts of diatomaceous silica is the most likely cause for the sorption of sulphate from the lake water.

TABLE 5

The relative sorptive powers of sulphate-free muds compared with that of commercially pure diatomite

	Diatomite	Mud from Pilkington Bay	Mud from Thruston Bay
p.p.m. $\text{SO}_4\text{-S}$ in added solution	100	100	100
p.p.m. $\text{SO}_4\text{-S}$ in extract	49	47	97

As no mechanism could be envisaged whereby pure silica could directly sorb sulphate it was assumed that the sorption is due to some other substance intimately associated with the diatomite. For example it is known that diatomite can sorb aluminium hydroxide (BALY et al. 1935) and as shown by SCHMÄH, 1946), aluminium hydroxide under alkaline conditions can sorb sulphate. Similar sorption processes occur with ferric hydroxide.

Thus, as a further investigation into the phenomenon, a sample of the commercial diatomite was digested with a mixture of nitric and hydrochloric acids. The extract was analysed for calcium, aluminium and iron and the purified diatomite was washed and dried.

The commercial diatomite contained 0.05% Ca  
0.003% Al  
0.164% Fe

Sorption experiments were then carried out on the commercial diatomite and the pure diatomite using solutions of potassium sulphate, calcium sulphate, aluminium sulphate and ferric sulphate under acid and alkaline conditions. These experiments are set out in Table 6 on which the following discussion is based.

TABLE 6

Sulphate-sorption experiments with commercial and pure diatomite

Solution added	$\text{SO}_4\text{-S}$ added p.p.m. soln.	$\text{SO}_4\text{-S}$ sorbed p.p.m. solution			
		Commercial diatomite pH 6	Pure diatomite pH 9	Pure diatomite pH 6	Pure diatomite pH 9
$\text{K}_2\text{SO}_4$	100	35	96	38	21
$\text{CaSO}_4$	100	9	61	35	48
$\text{Al}_2(\text{SO}_4)_3$	100	40	76	24	52
$\text{Fe}_2(\text{SO}_4)_3$	100	32	78	6	34
$\text{CaSO}_4$ + oxine	100	—	—	—	38
$\text{Al}_2(\text{SO}_4)_3$ + oxine	100	31	75	—	27
$\text{Fe}_2(\text{SO}_4)_3$ + oxine	100	34	76	—	10

Under mildly acid conditions the commercial diatomite sorbed appreciable amounts of sulphate but at pH 9 such sorption was very much greater, about three quarters of the added sulphate being sorbed. The presence of oxine had no effect indicating that iron and aluminium were not involved to any great extent in the sorption process. With pure diatomite calcium sulphate was sorbed to a far greater extent at pH 6 than with commercial diatomite and its sorption was still high at pH 9 which suggests that the presence of calcium is sufficient to make sulphate sorption possible. The sorption of aluminium and iron sulphates was reduced at both pH 6 and 9 showing that although some sorption may be due to the presence of iron or aluminium these elements are not so markedly involved as is calcium.

Thus the evidence all points to calcium as being the chief substance which, in close association with diatomite, is responsible for sulphate sorption.

This conclusion is supported by the fact that whereas oxine has no effect upon the sorption of sulphates by commercial diatomite and lake mud diatomite which both contain calcium, and has no effect upon the sorption of calcium sulphate by pure diatomite, it does reduce the small sorption of iron and aluminium sulphates by pure diatomite. The iron or aluminium become fixed by the oxine by complex formation and thus leave the sulphate in solution where, in the absence of any calcium to aid its sorption, it remains.

It has been found by BARBIER (1938) that the presence of calcium favours the sorption of sulphates by soils independently of mere fixation by calcium sulphate formation and it may well be that a similar effect occurs in diatomite-rich muds.

## CONCLUSION

It seems apparent that sulphur deposited on the bed of Lake Victoria in organic forms such as plant debris, has little chance of decomposition into an available form. Furthermore, experimental evidence indicates that sulphate-sulphur incorporated into the muds is being fixed in some manner. Where diatom frustules account for most of the silica in the mud, then part of the sulphate loss can be explained by sorption, and in such cases not only is the sulphate withheld from solution into the lake water, but is it protected from reduction. The sorption of sulphate appears to be due mainly to calcium which is in close association with the diatomite. The protection from reduction effect has yet to be further investigated but it is of interest to note that CATRAVAS (1954) found that hydrogen sulphide had

hardly any effect upon a nickel catalyst suspended in diatomite whereas it at once reduced the same catalyst when free from diatomite.

## ACKNOWLEDGEMENTS

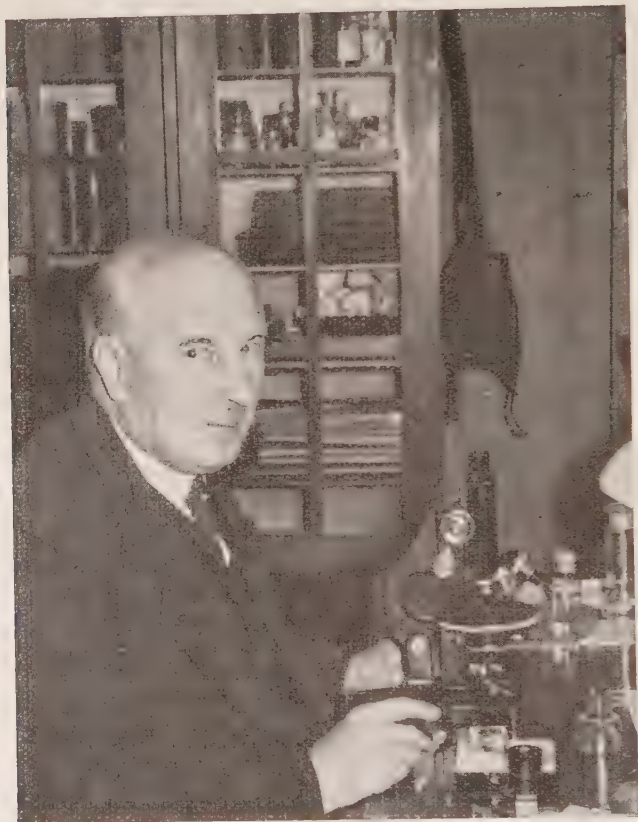
Much of the work described was carried out whilst on a visit to the laboratories of the East African Fisheries Research Organisation and the author wishes to thank the Director, Mr. R. S. A. BEAUCHAMP for the facilities provided.

Tanks are also due to Mr. BEAUCHAMP for many suggestions including the valuable one that diatom frustules in the muds may be responsible for the sorption of sulphates.

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## Prof. Dr. August Thienemann 75 years



Prof. Dr. AUGUST THIENEMANN

In a review like *HYDROBIOLOGIA* it is not necessary to say that AUGUST THIENEMANN is one of the greatest hydrobiologists of our time.

But his work is so important that we think many of our readers will be interested in having a survey of what this man has done.

Born on September 7, 1882 in Gotha as son of the publisher FRIEDRICH THIENEMANN, he did zoological studies at different universities:

Greifswald, Innsbrück, Heidelberg, and became an assistant at the zoological institution of Greifswald in 1904.

In 1905, at the same university, he took his dr. phil. degree, summa cum laude. Already in 1907 he was entrusted with the direction of the hydrobiological section of the Agricultural Research Station at Münster. In 1914 he was mobilized and soon heavily wounded.

From 1917 he was director of the Hydrobiological Station of the „Kaiser Wilhelm Gesellschaft zur Förderung der Wissenschaften“ at Plön.

After two months he also became an extraordinary professor at the university of Kiel charged with the courses of hydrobiology.

In 1924 he was promoted to ordinary professor at the same university. From 1928 to 1929 he undertook the well-known expedition to Java, Sumatra and Bali. (Deutsche Limnologische Sunda Expedition.)

Since 1916 he has the direction of the „Archiv für Hydrobiologie“ and since 1925 of the famous series „Die Binnengewässer“, in which there appeared the work of HUBERT PESTALOZZI and so many others.

In 1922 he founded the International Association of Limnology and was its first president, which function he occupied until 1939. From this date, this international organism elected him as an honorary president.

He is a member, corresponding member and honorary member of a large number of scientific societies and academies and one of the scientists who received the Einar Naumann medal.

He also was awarded many distinctions, but his greatest and most important merit lies in what he achieved in the field of hydrobiological research.

His numerous excellent papers on Chironomids, Planaria and on general hydrobiological subjects, hydrobiology, ecology and geographical distribution of freshwater organisms number to more than 450. Most of them surely are of lasting importance.

We hope that he will go on working for many years to come, because every publication of THIENEMANN is worth being read.

P. VAN OYE

# Bibliography

DAMAS, H.: Etude limnologique de quelques lacs ruandais. I. Le cadre géographique 1954; II. Etude thermique et chimique 1954; III. Le plancton 1955; IV. Les sédiments et leurs faunes. Conclusions générales 1956. Acad. roy. sc. colon. Brux. Classe d. sc. nat. et méd. Mém.

We already have announced the four parts of this work in the bibliography of this journal. Now that it is completed, we want to say that prof. H. DAMAS of Liège has done an excellent job, for it is the first time that the lakes of Ruanda have been examined.

In part I (1954) the author gives all the data concerning the geography of the various lakes he examined adding accurate transverse sections of them.

It is sorry the author sometimes drew cross-sections on which the depth has a scale ten times larger than that of the length. So our first impression is that the bottom of those lakes is very accidented. To those acquainted with transverse sections it is of course no hindrance that there is but little accidentation in a line rendering the transverse profile. The second part (1954) examines the thermic and chemical conditions of the lakes. The fourth part (1956) analyzes the sediments and their fauna.

These three parts (I, II, IV) will be for a long period to come a leading work for the study of the Ruanda lakes.

The third part (1955) gives the results of the plankton studies. Here the author had the assistance of various specialists: DE BEAUCHAMP from Paris for the Rotifers, V. BREHM from Lunz for the Cladoceres, F. KIEFER from Constance for the Cyclopids, F. HUSTEDT from Bremen for the Diatoms and J. SYMOENS from Brussels for the Cyanophyceae and other algae. In the first place the plankton is considered from a view-point of biological productivity of the various lakes. Yet from a taxonomical and biological view-point data as: *Cosmarium* sp., present or absent, Flagellates, *Anabena* sp. . . . have no value.

We regret that this part cannot be considered as being of the same standing as the three others. But as a whole the work of DAMAS is of high quality.

P. v. O.

DONNER, JOSEF: Rädertiere (Rotatorien). Kosmos-Verlag Franckh. Stuttgart. 50 pp. 4 plates (88 figg.) 7.80 D.M.

This little book is not conceived as a handbook for specialists. Nevertheless I think it necessary to draw the attention to it because it happens to be the only survey of the latest data concerning Rotifers.

It is written by a specialist who realized an exhaustive outline of the subject. Of course it is not feasible to determine the species of Rotatoria. Yet this was not the author's aim.

As an introduction to the knowledge of Rotifers, it certainly is a work with excellent qualities of clearness and conciseness.

P. v. O.

FOWLER, H. W.: Fishes of the Red Sea and Southern Arabia. 1956, Jerusalem, the Weizmann Science Press of Israel, 240 pp., 117 figg.

For years dr. H. W. FOWLER, curator of fishes of the Academy of Natural Sciences of Philadelphia, has been one of the most renowned ichthyologists.

Consequently this is a first-rate study. It has short but excellent descriptions, giving all the necessary details for determining the various species.

The illustrations too are quite simple, yet strikingly expressive, as they render all morphological characteristics. The whole work will be complete in three volumes.

This first volume treats the Branchiostomida to the Polynemida. Vol. 2 will treat the Percida and vol. 3 the Dactylonterida to the Lophida beside fresh water fishes. There are keys to orders, families and genera, sometimes to species.

P. v. O.

GEISSNER, FRITZ: Meer und Strand. 1957, XI, 395 pp. 210 figg. 10 tables 15.80 D. M.

This is the second edition, revised and enlarged. In this case it really means that the work was overhauled and quite extended. Some parts entirely have been re-adapted since the first edition in 1931.

Numerous coloured photos are the result of the latest journeys of the author. FRITZ GEISSNER, who is known for his remarkable ability of exposing a subject to non-specialists, has treated the subject with extreme thoroughness. There are two small observations to be made. First, the literature is for the greatest part of German origin and for a smaller part mainly Scandinavian.

It is true that if it were written by a Frenchman, an Englishman or an American, equivalent shortcomings would be perpetrated. Yet this is no excuse for whatever author who considers science as an international subject.

The second weakness is to be found in the explanation of the origine of dunes, where the author does not mention the work of VAN DIEREN, written in German: „Organogene Dünenbildung“ (1934).

As a whole the work is presented in a very refined way, with excellent coloured plates and 210 figures in the text.

P. VAN OYE.

SELLERY, G. C.: E. A. Birge, A Memoir. MORTIMER, C. H.: An Explorer of Lakes. The University of Wisconsin Press, Madison 1956, \$ 3.50, 221 pp.

This biography gives a portrait of a man and his work, EDWARD ASAHIEL BIRGE, an American limnologist, born in 1851 and deceased in 1950, fifteen months short of his hundredth birthday.

He started in 1876 as a young instructor in natural history and advanced through academic ranks to deanship and presidency. The parallel growth of the man and the University of Wisconsin to which he devoted his life is traced by Dean Emeritus G. C. SELLERY, a colleague and neighbour. In his seven chapters Dean SELLERY relates the activities by which BIRGE came to be known as scholar and administrator.

He dedicates a special chapter to BIRGE as a religious man. It is quite interesting, though not usual, to make such complete acquaintance of a scientist.

From an added essay „An Explorer of Lakes“ by C. H. MORTIMER, hydrobiologist of the Freshwater Biological Association, Ambleside, England, we learn all about BIRGE's work in the field of limnology. So we are granted a remarkable picture of one of the greatest limnologists of America, showing us the man and the scientist as well as the influence he exerted in his environment.

P. VAN OYE

TAYLOR, WILLIAM RANDOLPH: Marine Algae of the Northwestern Coast of North America.

1957, Ann Arbor, University of Michigan Press, 2nd revised edition 509 pp. 60 plates, \$ 12.50.

In recent years marine algae more and more were taken as a subject of studies. Consequently it is of fundamental value that larger works treating the subject more generally are being published.

Alongside with other works, such as e.g. that by KYLING on the marine algae of the Swedish coast, the study of TAYLOR is preparing the basis for a survey of all marine algae of the world, their geographical distribution, ecology and geography from a universal view-point. It is the result of more than 25 years of research on the subject and it will be for years to come one of the standard works to be consulted.

P. v. O.

THIENEMANN, A.: Chironomus. Leben, Verbreitung und Wirtschaftliche Bedeutung der Chironomiden. Die Binnengewässer, Bd. 20, 1954, 834 pp.

This monumental work on Chironomids is one of those that all specialists must possess. It is not possible to describe in a few lines the contents of this huge volume. Let us only say that THIENEMANN is the great specialist on Chironomids. He has treated the subject in all its aspects and with the thoroughness of a scientist who has devoted the greatest part of his life to making studies on this group of insects. Pages 1—31 may be considered as an introduction with a very short historical survey containing photographs of J. J. KIEFER, M. GOETGHEBUER, F. W. EDWARDS, J. ZAVREL and O. A. JOHANNSEN.

The author dedicates a first chapter to the life of Chironomids, a second chapter to their distribution and a third to their economical aspect.

If we add that the literature takes up pages 653 to 800, viz. 148 pages, one realizes that anything of some value that has been published on this subject was considered.

A work of this scope amazes us by its proportions and inspires respect for the amount of work done by a single man.

P. v. O.

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An important and extremely well documented review, very valuable to those who are interested in Australian marine or fresh water questions.

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New species: *Achnanthes austriaca* HUST. var *dracomontana*, *Achnanthes Rautenbachiae*, *Cymbella anassae*, *Cymbella Rautenbachiae*, *Cymbella subventricosa*; *Diploeis tugulae*, *Gomphonema perminuta*; *Navicula anassae*, *Navicula Artemidis*, *Navicula bryophyla* PETERSEN var. *trigibla*, *Navicula cavernae*, *Navicula natalensis*, *Navicula Rautenbachiae*, *Navicula zulu*, *Nitzschia anassae*, *Nitzschia Rautenbachiae*, *Pinnularia anassae*, *Stauroneis dracomontana*, *Surirella anassae*.

CSEPA, O. - Ueber das Filtergesetz der Grundwasserbewegung. *Acta Hydrophysica* 1955—1956, Bd 3 pp 181—198.

CSEPA, O. - Ueber den Wärmehaushalt des Breiten Lucin- und Haussees bei Feldberg (Mecklonb.). *Acta Hydrophysica* 1955—1956, Bd 3, pp 161—180, 4 figg Tabel.

# **NINTH INTERNATIONAL BOTANICAL CONGRESS**

The Ninth International Botanical Congress will be held in Montreal, Canada, from August 19 to 29, 1959, at McGill University and the University of Montreal, and will be preceded by sessions of the Bureau of Nomenclature from August 16 to 19

## **PROGRAM**

The program of the Congress is being organized and tentatively includes the following sections:

Nomenclature

General Systematics (including special problems) and  
Phylogeny

Taxonomy and Geography of Vascular Plants

Phycology

Mycology (including Medical Mycology)

Phytopathology (including Virology)

Bryology

Lichenology

Microbiology

Morphology and Anatomy

Paleobotany

Physiology

Ecology

Cytology and Genetics

Forest Botany

Ethnobotany and History of Botany

The Second Circular will give instructions as to the length of abstracts and other details. Abstracts of contributed papers must be with the Secretary-General, IX International Botanical Congress, Science Service Building, Ottawa, Canada, by March 15, 1959. **Please do not send abstracts until you receive the Second Circular.**

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